



U.S. Army
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Luckey Site

Luckey, Ohio

Feasibility Study Report

FINAL

Prepared for:

**U.S. Army Corps of Engineers
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*contributed to the preparation of this document and
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ACRONYMS, ABBREVIATIONS, & SYMBOLS

°C	Degrees Celsius
ACS	American Cancer Society
ADD	average daily dose
AEC	Atomic Energy Commission
ALARA	as low as reasonably achievable
amsl	above mean sea level
ARAR	Applicable or Relevant and Appropriate Requirement
BBC	Brush Beryllium Company
bgs	below ground surface
BNI	Bechtel National Incorporated
BRA	baseline risk assessment
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CL	Lean Clay
COC	constituent of concern
COPC	constituent of potential concern
CPEC	constituent of potential ecological concern
cy	cubic yards
DCGL	derived concentration guideline level
DOE	Department of Energy
DOT	Department of Transportation
DPC	Defense Plant Corporation
DQO	Data Quality Objective
EEQ	environmental effects quotient
EMC	elevated measurement comparison
EPA	Environmental Protection Agency
EPC	exposure point concentration
ERA	ecological risk assessment
EU	exposure unit
FS	Feasibility Study
ft	foot
FUSRAP	Formerly Utilized Sites Remedial Action Program
FY	Fiscal Year
gal	gallon
gal/min	gallons per minute
GCS	General Sciences Corporation
GRA	General Response Action
HASP	Health and Safety Plan
HHRA	Human Health Risk Assessment
HI	hazard index
hr	hour
HQ	Hazard Quotient
HSRC	Hazardous Substance Research Centers
HVAC	heating, ventilation and air conditioning
IA	Investigative Area
IDW	Investigative Derived Waste
IEUBK	Integrated Exposure Uptake Biokinetic Model
ILCR	incremental lifetime cancer risk
Kd	Distribution coefficient

ACRONYMS, ABBREVIATIONS, & SYMBOLS

LIBS	Laser Induced Breakdown Spectroscopy
LOSA	Lake Ontario Storage Area
LTP	License Termination Plan
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
m	Meters
MCL	maximum contaminant level
mg/kg	milligrams per kilogram
mg/l	milligrams per liter
MNA	monitored natural attenuation
mrem/yr	millirem per year
MWH	Modified Warmwater Habitat
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NPDES	National Pollution Discharge Elimination System
NPDWR	National Primary Drinking Water Regulation
NRC	Nuclear Regulatory Commission
OAC	Ohio Administrative Code
Ohio DOH	Ohio Department of Health
Ohio DNR	Ohio Department of Natural Resources
Ohio EPA	Ohio Environmental Protection Agency
O&M	Operation and Maintenance
ORNL	Oak Ridge National Laboratory
Pa-231	Protactinium-231
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
pCi/g	picocuries per gram
pCi/L	picocuries per liter
pH	Potential of Hydrogen
POTW	Publicly Owned Treatment Works
PP	Proposed Plan
ppb	parts per billion
PPE	Personal Protective Equipment
ppm	parts per million
PVC	polyvinyl chloride
QA	Quality Assurance
QC	Quality Control
RA	Remedial Action
Ra-226	Radium-226
RAGS	Risk Assessment Guidance for Superfund
RAO	Remedial Action Objective
RBC	risk-based concentration
RCRA	Resource Conservation and Recovery Act
redox	reduction-oxidation
RESRAD	Residual Radiation Computer Code
RI	Remedial Investigation
ROD	Record of Decision
SAIC	Science Applications International Corporation
SAP	Sampling and Analysis Plan
SDWA	Safe Drinking Water Act
SESOIL	Seasonal Soil Compartment Model

ACRONYMS, ABBREVIATIONS, & SYMBOLS

SOR	sum of ratios
SVOC	semi-volatile organic compound
TBC	to be considered
TEDE	Total Effective Dose Equivalent
TERP	Transportation and Emergency Response Plan
Th-228	Thorium-228
Th-230	Thorium-230
Th-232	Thorium-232
Th-234	Thorium-234
TOSC	Technical Outreach Services for Communities
TRPH	total recoverable petroleum hydrocarbons
TRV	toxicity reference value
TRW	Technical Review Workgroup
TSCA	Toxic Substances Control Act
U-233	Uranium-233
U-234	Uranium-234
U-235	Uranium-235
U-238	Uranium-238
UMTRAP	Uranium Mill Tailings Remedial Action Program
UMTRCA	Uranium Mill Tailings Radiation Control Act
USACE	United States Army Corps of Engineers
USFWS	United States Fish and Wildlife Service
UST	underground storage tank
UTL	upper tolerance limit
VOC	Volatile Organic Compound
WL	Working Level
WWH	Warmwater Habitat
µg/dL	micrograms per deciliter
µg/L	micrograms per liter
µL	microliters
µR/h	microRoentgen per hour

ES.0 EXECUTIVE SUMMARY

This Feasibility Study (FS) Report details the development, screening, and evaluation of remedial alternatives for the Luckey site, located just north of Luckey, Ohio. In 1991, the site was designated as eligible for inclusion in the Formerly Utilized Sites Remedial Action Program (FUSRAP). FUSRAP was established to remediate sites impacted by activities of the Atomic Energy Commission (AEC) in the early years of the Nation's atomic energy program.

The United States Army Corps of Engineers (USACE), as the lead federal agency for the remediation of the Luckey site, is required by law to execute FUSRAP in accordance with the administrative, procedural, and regulatory provisions of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) (42 U.S.C. 9601 et seq.) and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (40 CFR 300). The feasibility study, yielding an FS Report, is performed to ensure appropriate remedial alternatives are developed and evaluated such that relevant information concerning the remedial action options can be presented to a decision-maker and an appropriate remedy can be selected. Development of the alternatives must take into account site-specific conditions and factors. The NCP requires specific criteria be evaluated regarding each alternative including its protectiveness of human health and the environment and its compliance with applicable or relevant and appropriate requirements (ARARs).

ES.1 SCOPE

The scope is limited to addressing radioactivity, beryllium, and other constituents related to the production of beryllium at the Luckey site in support of the national defense program. These constituents generally are referred to as AEC-related constituents. Other constituents not related to AEC activities are not under the purview of USACE at the Luckey site and are not addressed in this FS unless co-located with AEC-related constituents or their presence constrains proposed activities to address AEC-related constituents.

Based on the conclusions of the Remedial Investigation (RI), the focus of this FS is the media contaminated by these AEC-related constituents. The baseline risk assessment developed in the RI Report divided the site into exposure units (EUs) to evaluate risks to various receptors. The RI concluded that both on-site and off-site soils, as well as groundwater, had been impacted by AEC-related activities and required further evaluation in this FS. Remedial action objectives (RAOs) to protect future receptors are developed in this FS for the following environmental media and AEC-related constituents:

- Impacted Soils (on-site and off-site soils/EUs 1,2, and 3):
beryllium, lead, radium, thorium, and uranium
- Site-Wide Groundwater (EU 7 within the confines of EUs 1, 2, and 3):
beryllium, lead, and uranium

ES.2 SUMMARY OF REMEDIAL ACTION OBJECTIVES

The RAOs developed in this FS Report address Impacted Soils and Site-Wide Groundwater for unrestricted land use and industrial land use. The intention of the RAOs is to provide long-term protection of human health and the environment. To provide this protection, the constituents of concern (COCs), the exposure routes and receptors (i.e. subsistence farmer and industrial worker) and an acceptable concentration for the long-term protection of receptors are specified.

The RAOs for the Impacted Soils and Groundwater units are as follows:

- Remove or prevent exposure to media containing concentrations of COCs that may pose a risk to human health in excess of a 10^{-4} incremental lifetime cancer risk and/or non-cancer hazard index of 1. Final COCs are limited to constituents associated with AEC activities.
- Minimize the transport of soil COCs to other environmental media (groundwater, surface water, sediment, and air).
- Monitor, control, or actively reduce COCs in groundwater to ensure that, within a limited period of time, concentrations of these constituents are reduced to or below the media-specific cleanup goals at an established point of compliance. The point of compliance and time period to achieve compliance will comply with federal and state law.
- Restore the site to a condition consistent with its current and anticipated future uses.
- Prevent releases and other impacts that could adversely affect ecological receptors during implementation of the remedial alternative(s).
- Comply with ARARs.

ES.2.1 Applicable or Relevant and Appropriate Requirements

ARARs are cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations published by the federal government, or state environmental or facility citing laws that either specifically address or are found sufficiently similar to circumstances at a CERCLA site. USACE has identified the following proposed ARARs for remedial activities at the Luckey site.

10 CFR Part 20 Subpart E – Radionuclides: 10 CFR Part 20 Subpart E is both relevant and appropriate for use in the development of media-specific cleanup goals at the Luckey site. The rule addresses situations sufficiently similar to the circumstances of the release at Luckey and its use is appropriate to the circumstances of the release. The standards in the 10 CFR Part 20 Subpart E are:

- Unrestricted use: total effective dose equivalent (TEDE) limited to 25 millirem per year (mrem/yr) for the unrestricted land use receptor and demonstrated to be as low as reasonably achievable (ALARA).
- Restricted use: 25 mrem/yr TEDE to the restricted land-use receptor, ALARA, durable land use controls, license termination plan (LTP), public input, and 100 mrem/yr or 500 mrem/yr to the unrestricted land use receptor if land use controls fail.
- Alternate criteria: 100 mrem/yr, ALARA, LTP, and EPA and public input.

OAC 3701:1-38-22 – Radionuclides: OAC 3701:1-38-22 contains limitations for radionuclides similar to those found in 10 CFR Part 20 Subpart E. The requirement has been promulgated by the State of Ohio, as an agreement state, to ensure consistent standards for determining the extent to which lands in the State of Ohio must be remediated before decommissioning of a site can be considered complete and the state license can be terminated. OAC 3701:1-38-22 establishes a standard for unrestricted release of property of 25 mrem/yr plus ALARA, as the total effective dose equivalent to an average member of a critical group. In Ohio, the critical group has been consistently defined as the subsistence farmer.

Maximum Contaminant Levels (MCLs) - Uranium and Beryllium in Groundwater: MCLs generally are relevant and appropriate to the cleanup of groundwater that is or may be used for drinking water because MCLs are the enforceable standards under the Safe Drinking Water Act (SDWA). The MCLs for carcinogens are within EPA's acceptable risk range and are protective of human health. At the Luckey site, the MCL value is being cited as the target media-specific cleanup goal. Only the MCL value is being cited as relevant and appropriate. Other provisions of 40 CFR § 141.66, such as monitoring and

reporting requirements, are not included. The monitoring and reporting requirements set forth in 40 CFR § 141.66 apply to community water systems that provide drinking water to consumers.

National Primary Drinking Water Regulations - Lead in Groundwater: This health standard found at 40 CFR § 141.80(c) and OAC 3745-81-80(C)(1) is promulgated as a treatment technique, with a trigger action level of 0.015 mg/L. An action level under the SDWA is the regulatory equivalent of an MCL for a drinking water contaminant. In requiring that National Pollution Drinking Water Regulations (NPDWRs) be established for drinking water contaminants, the SDWA provides standards that can be promulgated as MCLs or as treatment techniques.

ES.2.2 Selected Media-specific Cleanup Goals

Table ES.1 presents the selected media-specific cleanup goals for the Impacted Soils and Groundwater units for both the subsistence farmer and the industrial worker.

ES.3 REMEDIAL ALTERNATIVES

The Remedial Alternatives assembled for the Luckey site were constructed by combining general response actions, technology types, and process options retained from the screening process. The alternatives should assure adequate protection of human health and the environment, achieve RAOs, meet ARARs, and permanently and significantly reduce the volume, toxicity, and/or mobility of site-related contaminants. The most promising technologies were assembled into the following remedial alternatives:

- Alternative 1: No Action (Soils and Groundwater)
- Alternative 2: Limited Action (Soils and Groundwater),
- Alternative 3: Consolidation and Capping (Soils),
- Alternative 4: Excavation of Soils and Off-site Disposal (Soils) ~ Industrial Land Use
- Alternative 5: Excavation of Soils and Off-site Disposal (Soils) ~ Unrestricted Land Use
- Alternative 6: Excavation of Soils, Treatment, and Off-site Disposal (Soils) ~ Unrestricted Land Use
- Alternative 7: Monitored Natural Attenuation (Groundwater) ~ Unrestricted Land Use,
- Alternative 8: Active Groundwater Treatment – Ex Situ (Groundwater) ~ Unrestricted Land Use, and
- Alternative 9: Electrokinetics (Groundwater) ~ Unrestricted Land Use.

These remedial alternatives are summarized in Table ES.2.

ES.4 EVALUATION OF REMEDIAL ALTERNATIVES

A detailed evaluation of each alternative is performed to provide the basis and rationale for identifying a preferred remedy and preparing the Proposed Plan (PP). Overall protection and compliance with ARARs are threshold criteria that must be met by any alternative for it to be eligible for selection. The other criteria consist of short- and long-term effectiveness; reduction of contaminant toxicity, mobility, or volume through treatment; ease of implementation; and cost. These are the primary balancing criteria used to select a preferred remedy among alternatives satisfying the threshold criteria. Each remedial alternative is evaluated against the following criteria:

- overall protection of human health and the environment
- compliance with ARARs
- long-term effectiveness and permanence
- reduction in toxicity, mobility, or volume through treatment

- short-term effectiveness
- implementability
- cost

A summary of this evaluation is included in Table ES.3. Site characterization data and a number of analytical tools provide the foundation for evaluation of the alternatives.

The alternatives also undergo a comparative analysis for the purpose of identifying relative advantages and disadvantages of each on the basis of the detailed analysis above. The comparative analysis provides a means by which remedial alternatives can be directly compared to one another with respect to common criteria. Table ES.4 summarizes the comparative analysis of the remedial alternatives. Community and state acceptance criteria are preliminarily assessed and will be fully addressed after the public comment period.

The detailed and comparative analyses indicated Alternatives 5 and 6 for soil and Alternatives 7, 8, and 9 for groundwater meet media-specific cleanup goals and allow the site to be released for unrestricted use. Alternative 4 provides overall protection and meets the ARAR dose limits even if land use controls fail. However, the site could not be released for unrestricted use because beryllium and lead would remain above unrestricted land use cleanup goals. Alternative 3 provides overall protection, but would not allow portions of the site to be released for unrestricted use. Alternative 2 provides overall protection, but would not allow the site to be released for unrestricted use. Alternative 1 is not protective and therefore would not allow the site to be released for unrestricted use.

The estimated costs for addressing soils in Alternatives 5 and 6 are much greater than Alternatives 2 and 3, but Alternatives 5 and 6 do not result in contaminated material remaining on site. The inclusion of treatment of soil in Alternative 6 does not provide a significant cost benefit over soil excavation and direct disposal alone (Alternative 5). The treatment of groundwater in Alternatives 8 and 9 is more costly in the short-term than Alternative 7 however the duration of time to achieve free release is shorter. The timeframe to achieve groundwater cleanup goals is shortest under Alternative 9.

The preferred remediation alternative is presented in the PP for the Luckey site. The USACE prefers Alternative 5, Excavation of Soils and Off-site Disposal (Soils) – Unrestricted Land Use, to address the impacted on-site soils and soils contiguous to the site in conjunction with Alternative 7, Monitored Natural Attenuation (groundwater). While Alternative 5 is not the least costly of the soils alternatives, it is considered to be the most protective both in the short- and long-term and is permanent- all soils exceeding unrestricted land use cleanup goals will be removed from the Luckey Site. This complete removal also precludes any further potential for contamination of groundwater. Monitoring of groundwater at the site over the past four years indicates a general decline in the uranium and lead concentrations, thus suggesting natural attenuation is already occurring. A Performance Monitoring Program will be conducted at the Luckey site to evaluate the remedy effectiveness and to ensure protection of human health and the environment. This monitoring program will be used:

- to demonstrate natural attenuation is occurring according to expectations,
- to determine if the area of existing contamination is expanding,
- to ensure no impact to down-gradient receptors,
- to detect new releases,
- to detect changes in environmental conditions that may impact the natural attenuation process, and
- to verify attainment of the clean-up objectives.

If the Performance Monitoring Program demonstrates that there are changes to environmental conditions or that the attenuation process is not proceeding as expected, then decisions regarding appropriate corrective actions will be made.

Table ES.1. Selected Media-specific Cleanup Goals for Luckey Site

IMPACTED SOILS			
Receptors	COC	Media-specific Cleanup Goal^a	Source
Current/Future Industrial Worker	Lead	958 mg/kg	RBC
	Radium-226	8.1 pCi/g ^{b,d}	ARAR
	Thorium-230	23 pCi/g ^{b,d}	ARAR
	Uranium-234	71 pCi/g ^{b,d}	ARAR
	Uranium-238	73 pCi/g ^{b,d}	ARAR
Future Subsistence Farmer	Beryllium	131 mg/kg	RBC
	Lead	400 mg/kg	RBC
	Radium-226	2.0 pCi/g ^{c,d}	ARAR
	Thorium-230	5.8 pCi/g ^{c,d}	ARAR
	Uranium-234	26 pCi/g ^{c,d}	ARAR
	Uranium-238	26 pCi/g ^{c,d}	ARAR
GROUNDWATER			
Receptors	COC	Media-specific Cleanup Goal^a	Source
Current/Future Industrial Worker	Beryllium	4 µg/L	ARAR
	Lead	15 µg/L	ARAR
	Uranium (total)	30 µg/L	ARAR
Future Subsistence Farmer	Beryllium	4 µg/L	ARAR
	Lead	15 µg/L	ARAR
	Uranium (total)	30 µg/L	ARAR

^a SESOIL modeling results indicate risk-based and/or ARAR-based cleanup goals selected for soils are protective of groundwater.

^b These cleanup goals represent activity levels above site background activity corresponding to 25 mrem/yr or 100 mrem/yr (whichever corresponding activity is more conservative – refer to Table 3.2) for remedial alternatives that include loss of land use controls i.e. restricted land use.

^c These cleanup goals represent activity levels above site background activity corresponding to 25 mrem/yr.

^d If a mixture of radionuclides is present, then the sum of ratios applies per MARSSIM. For example, using the unrestricted land use cleanup goals for soil, the following sum of ratios equation is obtained:

$$SOR = \frac{Ra - 226}{2.0 \text{ pCi/g}} + \frac{Th - 230}{5.8 \text{ pCi/g}} + \frac{U - 234}{26 \text{ pCi/g}} + \frac{U - 238}{26 \text{ pCi/g}}$$

where

SOR = sum of the ratios result

Ra-226 = net Ra-226 soil concentrations

Th-230 = net Th-230 soil concentrations

U-234 = net U-234 soil concentrations

U-238 = net U-238 soil concentrations

Net soil concentrations exclude background.

Table ES.2. Summary of Remedial Alternatives

<p>Alternative 1 – No Action (Soils and Groundwater)</p> <p>This alternative would provide no further remedial action at the Luckey site and is included as a baseline against which other alternatives can be compared. Although land use controls are in place at the site, these would be left in place, but not necessarily maintained under this alternative. However, the site is assumed to operate in compliance with existing regulations that impose limitations on occupational exposures. Five-year reviews would be conducted in accordance with CERCLA 121(c).</p>
<p>Alternative 2 – Limited Action (Soils and Groundwater)</p> <p>This alternative would involve limited site improvements, maintenance, attenuation, periodic monitoring (i.e., soil, surface water, sediment, groundwater, and air) to detect any changes in the nature or extent of contamination at the site. Land use controls would include continuing the existing and installing new access restrictions; maintaining cover materials including grass and asphalt; maintaining fencing and signs; land use restrictions to prohibit changes in land and groundwater uses or construction in impacted soils; and periodic inspection of the site to determine any changes in land use. Remedial action would require zero years to complete and would include a 1,000 year O&M period. Five-year reviews would be conducted in accordance with CERCLA 121(c).</p>
<p>Alternative 3 – Consolidation and Capping (Soils)</p> <p>This alternative would involve consolidating impacted soils above unrestricted land use cleanup goals and covering with a multi-layer cap consisting of clay and synthetic liners to limit exposures and minimize contaminant migration. Impacted soils on-site and directly adjacent to the site would be consolidated at an on-site location. The capped portion of the site would be subjected to land use controls, while the remaining portion would be available for unrestricted land use. Land use controls would include continuing the existing and installing new access restrictions; maintaining cover materials including grass and asphalt; maintaining fencing and signs; land use restrictions to prohibit changes in land and groundwater uses or construction in impacted soils; and periodic inspection of the site to determine any changes in land use. Periodic environmental monitoring (i.e., soils, surface water, sediment, and groundwater) would be conducted to assess contaminant migration. Remedial action would require 2 years to complete and would include a 1,000 year O&M period. Five-year reviews would be conducted in accordance with CERCLA 121(c).</p> <p>Alternative 7, 8, or 9 would be implemented with this alternative to remediate groundwater. The impact of this alternative on each of the groundwater alternatives is the same.</p>
<p>Alternative 4 – Excavation of Soils and Off-site Disposal (Soils) ~ Industrial Land Use</p> <p>This alternative would involve the removal and transportation of impacted soils above industrial land use cleanup goals for off-site disposal. Impacted soils would be excavated and transported to an off-site disposal facility licensed or permitted to accept these wastes. Clean backfill would be placed in excavated areas. Land use controls would include continuing the existing access restrictions; land use restrictions to prohibit changes in land uses; and periodic inspection of the site to determine any changes in land use. Periodic environmental monitoring (i.e., soils, surface water, and sediment) would be conducted to assess potential for off-site contaminant migration. Remedial action would require 1.7 years to complete and would include a 1,000 year O&M period. Five-year reviews would be conducted in accordance with CERCLA 121(c).</p> <p>Alternative 7, 8, or 9 would be implemented with this alternative to remediate groundwater. The impact of this alternative on each of the groundwater alternatives is the same.</p>
<p>Alternative 5 – Excavation of Soils and Off-site Disposal (Soils) ~ Unrestricted Land Use</p> <p>This alternative would involve the removal and transportation of impacted soils above unrestricted land use cleanup goals for off-site disposal. Impacted soils would be excavated and transported to an off-site disposal facility licensed or permitted to accept these wastes. Clean backfill would be placed in excavated areas. Remedial action would require 3 years to complete. There is no O & M associated with this alternative because impacted soils are removed from the site.</p> <p>Alternative 7, 8, or 9 would be implemented with this alternative to remediate groundwater. The impact of this alternative on each of the groundwater alternatives is the same.</p>

Table ES.2. Summary of Remedial Alternatives

Alternative 6 – Excavation of Soils, Treatment, and Off-site Disposal (Soils) ~ Unrestricted Land Use

This alternative is similar to Alternative 5 with respect to the excavation and transportation of soils, cleanup goals, and off-site disposal of impacted soils. However, this alternative incorporates treatment to reduce the volume of contaminated materials requiring disposal. Soils successfully treated to meet cleanup goals would be used as backfill in excavated areas. Impacted soils and treatment residuals above unrestricted land use cleanup goals would be transported to an off-site disposal facility licensed or permitted to accept these wastes. Remedial action would require 3 years to complete. There is no O & M associated with this alternative because impacted soils are removed from the site.

Alternative 7, 8, or 9 would be implemented with this alternative to remediate groundwater. The impact of this alternative on each of the groundwater alternatives is the same.

Alternative 7 -- Monitored Natural Attenuation (Groundwater) ~ Unrestricted Land Use

This alternative consists of monitoring the reduction in groundwater contaminant concentrations over time and would be implemented in conjunction with Alternative 3, 4, 5, or 6, which effectively remove the sources contributing to groundwater contamination. The impact of Alternatives 3, 4, 5, and 6 on the groundwater would be the same, removal of the source material. Groundwater remedial action would require zero years to complete with a potential 150-year O&M period for groundwater monitoring. Groundwater monitoring would be conducted in accordance with the monitoring program for the first five to 10 years after source removal, after which the efficacy of MNA will be confirmed. Land use controls would include land use restrictions to prohibit changes in groundwater use and periodic inspection of the site to determine any changes in land use. Five-year reviews would be conducted in accordance with CERCLA 121(c).

Alternative 8 – Active Groundwater Treatment, Ex situ Treatment (Groundwater) ~ Unrestricted Land Use

This alternative consists of actively treating groundwater contaminant concentrations using a pump and treat system involving adsorption of uranium and beryllium onto solid media. It would be implemented in conjunction with Alternative 3, 4, 5, or 6, which effectively remove the sources contributing to groundwater contamination. The impact of Alternatives 3, 4, 5, and 6 on the groundwater would be the same; removal of the source material. Groundwater remedial action would require 80 years for beryllium and 10 years for uranium to complete with an 80-year O&M period for groundwater monitoring. Groundwater monitoring would be performed annually for the first 5 years after source removal to confirm effectiveness. Land use controls would include continuing the existing and installing new access restrictions; maintaining fencing and signs; land use restrictions to prohibit changes in groundwater use; and periodic inspection of the site to determine any changes in land use. Five-year reviews would be conducted in accordance with CERCLA 121(c).

Alternative 9 – Electrokinetics (Groundwater) ~ Unrestricted Land Use

Alternative 9 involves drilling a grid pattern of wells through the saturated clay to the fractured bedrock, and emplacement of electrodes encased in permeable membranes filled with electrolyte. The electrodes would be connected to a power source, and the metal contaminants in the groundwater would be driven to the anodes for removal and disposal. This alternative would be implemented in conjunction with Alternative 3, 4, 5, or 6, which effectively remove the sources contributing to groundwater contamination. The impact of Alternatives 3, 4, 5, and 6 on the groundwater would be the same; removal of the source material. Groundwater monitoring would be performed annually for the first 5 years after source removal for up to 15 years during electrokinetic treatment. Groundwater monitoring of constituents in bedrock would continue up to an additional 25 years. Land use controls would include continuing the existing and installing new access restrictions; maintaining fencing and signs; land use restrictions to prohibit changes in groundwater uses; and periodic inspection of the site to determine any changes in land use. Five-year reviews would be conducted in accordance with CERCLA 121(c).

Table ES.3 Summary of Detailed Analysis of Remedial Alternatives

NCP Evaluation Criteria	Alternative 1 No Action	Alternative 2 Limited Action	Alternative 3 Consolidation and Capping	Alternative 4 Excavation and Off-site Disposal (Industrial Land Use)	Alternative 5 Excavation and Off-site Disposal (Unrestricted Land Use)	Alternative 6 Excavation, Treatment, and Off-site Disposal (Unrestricted Land Use)	Alternative 7 Monitored Natural Attenuation (Unrestricted Land Use)	Alternative 8 Active Groundwater Treatment (Unrestricted Land Use)	Alternative 9 Electrokinetics (Unrestricted Land Use)
(1) OVERALL PROTECTIVENESS									
Human Health Protection	Not protective due to risk from exposure.	Not protective due to use of land use controls.	Protective due to reduction of contaminated area and mitigation of exposure pathways due to capping, and land use controls.	Protective due to removal of impacted soils from site and land use controls.	Protective due to removal of impacted soils from site.	See Alternative 5.	Protective due to natural attenuation and mitigation of exposure pathways due to land use controls.	Protective due to treatment of groundwater and land use controls.	See Alternative 7.
Environmental Protection	Continued potential for adverse impacts from existing conditions; however, habitat and receptors are limited.	See Alternative 1.	Action designed to address human health risks; however, this also will reduce risks to ecological receptors due to removal of impacted soils from site.	Action designed to address human health risks; however, this also will reduce risks to ecological receptors due to removal of impacted soils from site.	Action designed to address human health risks; however, this also will reduce risks to ecological receptors due to removal of impacted soils from site.	See Alternative 5.	Groundwater is not an ecological concern until it becomes surface water.	See Alternative 6.	See Alternative 6.
(2) COMPLIANCE WITH ARARs									
ARARs	Not compliant.	Would not comply for unrestricted release of property, property would not be released for unrestricted use.	Comply for industrial land use. Would not comply for unrestricted release of properties, portion of property would not be released for unrestricted use.	Comply for industrial land use. Would not comply for unrestricted release of property, property would not be released for unrestricted use.	Compliant.	Compliant.	Compliant in approximately 40 to 150 years.	Compliant in approximately 80 years.	Compliant in approximately 40 years.
(3) LONG-TERM EFFECTIVENESS AND PERMANENCE									
Magnitude of Residual Risk	Residual risk exceeds EPA risk range due to waste remaining in current configurations, thereby allowing for potential future exposure.	Residual risk is acceptable as long as land use controls are implemented and remain in place.	See Alternative 2.	See Alternative 2.	Meets risk range without restrictions on future land use. Less residual risk than Alts 1, 2, & 3.	See Alternative 5.	Meets risk range without restrictions. Would require a longer time frame to achieve than Alts 7 and 8.	See Alternative 6.	See Alternative 4.

Table ES.3 Summary of Detailed Analysis of Remedial Alternatives

NCP Evaluation Criteria	Alternative 1 No Action	Alternative 2 Limited Action	Alternative 3 Consolidation and Capping	Alternative 4 Excavation and Off-site Disposal (Industrial Land Use)	Alternative 5 Excavation and Off-site Disposal (Unrestricted Land Use)	Alternative 6 Excavation, Treatment, and Off-site Disposal (Unrestricted Land Use)	Alternative 7 Monitored Natural Attenuation (Unrestricted Land Use)	Alternative 8 Active Groundwater Treatment (Unrestricted Land Use)	Alternative 9 Electrokinetics (Unrestricted Land Use)
Adequacy and Reliability of Controls	No land use controls.	Land use controls considered adequate.	See Alternative 2.	See Alternative 2.	No land use controls required.	See Alternative 5.	Land use controls required and considered adequate while MNA works.	Land use controls required and considered adequate for duration of treatment.	Land use controls required and considered adequate for duration of treatment.
Long-Term Management	No long-term management.	Required since soils would remain on site above criteria for unrestricted use.	See Alternative 2.	See Alternative 2.	Not required.	See Alternative 5.	Required for up to 150 years or duration of treatment.	Required for 80 years.	Required for 40 years.
(4) REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT									
Reduction through Treatment.	None (no treatment).	See Alternative 1.	None.	None.	None.	Volume reduction.	None.	Volume and mobility reduction.	See Alternative 8.
(5) SHORT-TERM EFFECTIVENESS									
Community	Risk to community not increased, but potential contaminant migration and increased exposure over time.	See Alternative 1, although least risk to community.	Slight potential for an increase in risk from construction activities. Site risks would be controlled by mitigation measures.	See Alternative 3. Transportation risks introduced with off-site disposal.	See Alternative 3. Transportation risks introduced with off-site disposal.	See Alternative 5. Potential increase in risk due to additional materials handling during treatment. Site safety measures would be implemented to control risks.	Slight potential for an increase in risk during well installation activities. Site risks would be controlled by mitigation measures.	Slight potential for an increase in risk during well installation activities. Site risks would be controlled by mitigation measures.	Potential for an increase in risk from construction and implementation activities. Site risks would be controlled by mitigation measures.
Workers	No significant increase of risks or hazards to workers.	See Alternative 1.	Radiological risks and non-radiological hazards reduced by mitigation measures. Site safety measures would be implemented.	See Alternative 3.	See Alternative 3.	See Alternative 3. Potential for additional risks due to materials handling during treatment. Site safety measures would be implemented.	Slight potential of radiological and non-radiological hazards reduced by mitigation measures.	See Alternative 6. Potential for additional risks due to materials handling during treatment. Site safety measures would be implemented.	See Alternative 6. Potential for additional risks due to materials handling during treatment and electrical system needed for electrodes. Site safety measures would be implemented.
Ecological Resources	Continued potential for impacts from existing conditions.	Continued potential for impacts from existing conditions.	Potential short-term environmental impacts minimized by Engineering controls.	See Alternative 3.	See Alternative 3.	See Alternative 3.	Slight impact.	See Alternative 7.	Potential short-term environmental impacts minimized by Engineering controls.

Table ES.3 Summary of Detailed Analysis of Remedial Alternatives

NCP Evaluation Criteria	Alternative 1 No Action	Alternative 2 Limited Action	Alternative 3 Consolidation and Capping	Alternative 4 Excavation and Off-site Disposal (Industrial Land Use)	Alternative 5 Excavation and Off-site Disposal (Unrestricted Land Use)	Alternative 6 Excavation, Treatment, and Off-site Disposal (Unrestricted Land Use)	Alternative 7 Monitored Natural Attenuation (Unrestricted Land Use)	Alternative 8 Active Groundwater Treatment (Unrestricted Land Use)	Alternative 9 Electrokinetics (Unrestricted Land Use)
Engineering Controls	None.	See Alternative 1.	Potential releases controlled with management and engineering practices.	See Alternative 3.	See Alternative 3.	See Alternative 3.	See Alternative 3.	See Alternative 3.	See Alternative 3.
Time to Complete ¹	0 years	0 years	2 years	1.7 years	2.9 years	3 years	0 years	0.5 years	1 year
O & M Period	0 years	1,000 years	1,000 years	1,000 years	0 years	0 years	40 to 150 years	80 years	40 years
(6) IMPLEMENTABILITY									
Technical Feasibility	Not applicable.	Relatively easy.	Relatively easy. Readily available technology.	Relatively easy. Readily available technology.	Relatively easy. Readily available technology.	Moderate. Treatment units available commercially, but effectiveness must be demonstrated.	Relatively easy. Readily available technology.	Relatively easy. Readily available technology.	Moderate. Treatment units available commercially, but effectiveness must be demonstrated.
Administrative Feasibility	Not applicable.	May be difficult due to meeting substantive requirements the state has for licensing.	See Alternative 2.	See Alternative 2.	Relatively easy.	Would require meeting substantive requirements for placing “clean” soils back on site.	See Alternative 4.	See Alternative 4.	See Alternative 4.
(7) COST									
Estimated cost ²	\$0.0 million	\$1.1 million	\$17.6 million	\$29.3 million	\$36.5 million	\$42.8 million	\$0.83 million	\$3.7 million	\$9.4 million.
Cost with Alt 7	Not applicable.	Not applicable.	\$18.4 million	\$30.1 million	\$37.3 million	\$43.6 million	Not applicable.	Not applicable.	Not applicable.
Cost with Alt 8	Not applicable.	Not applicable.	\$21.3 million	\$33.0 million	\$40.2 million	\$46.5 million	Not applicable.	Not applicable.	Not applicable.
Cost with Alt 9	Not applicable.	Not applicable.	\$27.0 million	\$38.7 million	\$45.9 million	\$52.2 million	Not applicable.	Not applicable.	Not applicable.

¹ Time to complete remedial action after remedial design, is dependent upon timely project funding. Does not include O & M.

² Estimated costs calculated as net present value in FY 02 dollars using a seven percent discount factor.

Table ES.4. Summary of Comparative Analysis of Remedial Alternatives

NCP Evaluation Criteria	Alternative 1 No Action	Alternative 2 Limited Action	Alternative 3 Consolidation and Capping	Alternative 4 Excavation and Off-site Disposal (Industrial Land Use)	Alternative 5 Excavation and Off-site Disposal (Unrestricted Land Use)	Alternative 6 Excavation, Treatment, and Off-site Disposal (Unrestricted Land Use)	Alternative 7 Monitored Natural Attenuation (Unrestricted Land Use)	Alternative 8 Active Groundwater Treatment (Unrestricted Land Use)	Alternative 9 Electrokinetics (Unrestricted Land Use)
(1) Overall Protection of Human Health and the Environment	Low	Low	Medium	Medium	High	High	Low / Medium	High	High
(2) Compliance with ARARs	Low	Low	Medium / High	Medium / High	High	High	Low / Medium	High	High
(3) Long-Term Effectiveness and Permanence	Low	Low	Medium	Medium	High	High	Medium	High	High
(4) Reduction of Toxicity, Mobility, or Volume through Treatment	Low	Low	Low	Low	Low	Medium	Medium	High	High
(5) Short-Term Effectiveness (includes potential for environmental impacts) Time to complete ¹ O&M Period.	Low 0 years 0 years	Low 0 years 1,000 years	Medium 2 years 1,000 years	Medium 1.7 years 1,000 years	Medium 2.9 years 0 years	Medium 3 years 0 years	High 0 years 40 to 150 years	Medium 0.5 years 80 years	Low 1 year 40 years
(6) Implementability	High	Low	Low / Medium	Medium	High	Medium	High	Medium	Medium
(7) Cost ²	\$0	\$1.1 million	\$17.6 million	\$29.3 million	\$36.5 million	\$42.8 million	\$0.83 million	\$3.7 million	\$9.4 million
<i>Preliminary Evaluation of Regulatory and Public Input</i>									
(8) State / Agency Acceptance	Low	Low	Low / Medium	Low / Medium	High	High	Low	Medium	High
(9) Community Acceptance	Low	Low	Low	Low / Medium	High	Medium	Low	Medium	High

¹ Time to complete remedial action after remedial design, is dependent upon timely project funding. Does not include O & M.

² Estimated costs calculated as net present value in FY 02 dollars using a seven percent discount factor.

1.0 INTRODUCTION

This Feasibility Study (FS) Report details part of the ongoing evaluation of the Luckey site located in Luckey, Ohio. This is a draft version of the document. The work was performed for the United States Army Corps of Engineers (USACE) – Buffalo District by Science Applications International Corporation (SAIC), in conjunction with MWH Americas, Inc., under Contract DACW27-97-D-0015, Task Order Number 0009.

1.1 PURPOSE

This FS is one step in a process developed for characterizing the nature and extent of risks posed by hazardous waste sites and evaluating potential remedial alternatives. The process, in summary, consists of a preliminary assessment, site inspection, remedial investigation, and feasibility study, followed by remedy selection, record of decision, remedial design, and remedial action. The primary purpose of the feasibility study phase is to develop, screen, and evaluate remedial alternatives for a site using the data collected during the preceding remedial investigation (RI).

1.2 SCOPE

In 1997, the United States Congress delegated to the USACE lead authority for implementing the Formerly Utilized Sites Remedial Action Program (FUSRAP). FUSRAP was established in 1974 by the United States Atomic Energy Commission (AEC), and was later incorporated into the Department of Energy (DOE). The purpose of FUSRAP is to address contamination by radioactive and other hazardous substances at a number of sites resulting from past activities of the Manhattan Engineer District and the AEC in connection with the Nation's early atomic energy program. Pursuant to 10 U.S.C. § 2701 Note 1, all response actions undertaken by USACE at FUSRAP sites are subject to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (42 U.S.C. 9601 et seq.) and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (40 CFR 300).

The Luckey site was once used to process beryllium in support of the national defense program. The Luckey site was designated as eligible for inclusion in FUSRAP in 1991. In making this designation, the DOE authorized "remedial action for the observed radioactivity, the beryllium, and constituents related to the production of beryllium" at the Luckey site (DOE 1991a, b). USACE is authorized to address only these designated constituents at the Luckey site. In this FS, these constituents generally are referred to as AEC-related constituents. Other constituents not related to AEC activities are not under the purview of USACE at the Luckey site and are not addressed in this FS unless co-located with AEC-related constituents or their presence constrains proposed activities to address AEC-related constituents.

The RI was completed in four phases from 1998 to 2000 and consisted of the following: 1) preliminary records search, 2) field screening and limited intrusive sampling, 3) synthesis of existing data and planning for subsequent phase of sampling, 4) comprehensive sampling effort and evaluation including the baseline risk assessment. The RI sampling and evaluation activities encompassed on-site and off-site soils, groundwater, buildings, sediments, and surface water at the Luckey site and are documented in the RI Report (USACE 2000a). Based on the conclusions of the RI, the focus of this FS is contaminated or "impacted" soils and groundwater.

In the baseline risk assessment developed in the RI Report, the site was divided into exposure units (EUs) for the purpose of evaluating risks to various receptors (Section 2.4). These receptors are consistent with current and potential future land uses and include industrial workers, resident farmers, and adolescent trespassers as well as various ecological receptors. Evaluation of an additional receptor, the subsistence farmer, is included in this FS.

The Luckey site is zoned light industrial and is expected to remain industrial for the near future. Given the current zoning designation and published expansion plans for the Village of Luckey (Wood County 1998), the most likely future use of the property is industrial or commercial. However, it is possible future land use could be residential or agricultural for the following reasons: surrounding land use on three sides is agricultural and residential; agricultural and residential are the dominant land uses in Troy Township; there is no other industry in the area; and industrial facilities at the site are aging; and there are no current plans to replace or renovate them for continued industrial use.

The RI concluded on-site and off-site soils, as well as groundwater, had been impacted by AEC-related activities and required further evaluation in the FS. Remedial action objectives (RAOs) to protect future receptors are developed in this FS for the following environmental media and AEC-related constituents:

- Impacted Soils (on-site and off-site soils/EUs 1, 2, and 3):
beryllium, lead, radium, thorium, and uranium
- Site-Wide Groundwater (EU 7 within the confines of EUs 1, 2, and 3):
beryllium, lead, and uranium

Contaminated off-site soils requiring remediation are generally contiguous with contaminated on-site soils. Therefore, for the identification and evaluation of RAOs and remedial alternatives, these are combined into one unit collectively named “Impacted Soils.” The USACE has concluded that no action is warranted for the remaining exposure units evaluated in the baseline risk assessment.

The France Stone Quarry (EU 5) and the Troy Township Dump (EU 6) are located just south of the Luckey site. Analytical results, as discussed in the RI, do not indicate any unacceptable impacts at either unit as a result of AEC-related activities at the Luckey site. Thus, the RI Report concluded no further action is warranted and remedial alternatives for these units are not evaluated in this FS.

After evaluating the results of the RI for the on-site buildings, USACE has concluded there is no evidence of a release from the buildings, as defined by CERCLA, nor evidence of a substantial threat of a release of hazardous substances into the environment from the buildings. CERCLA defines the term “release” to mean “any spilling, leaking, pumping, pouring, emitting, emptying, discharging, injecting, escaping, leaching, dumping, or disposing into the environment”, and specifically excludes “... any release which results in exposure to persons solely within a workplace, ...”. Therefore, the buildings would not qualify to be addressed under CERCLA and are no longer within the scope of the CERCLA efforts being undertaken by USACE at the Luckey site.

Toussaint Creek (EU 4) and select tributaries require no further action. Toussaint Creek and all on-site and off-site drainage ditches (sediment, surface water, and meander bend soils) have been combined into one unit. Sediment sampling results reported in the RI and in samples collected in 2001 indicate there has been a release, as defined under CERCLA, to Toussaint Creek and its tributaries. The screening level ecological risk assessment performed in the RI did not adequately characterize risks to ecological receptors in order to develop RAOs. Additional biological and chemical sampling was conducted in Toussaint Creek in 2001 to further evaluate existing conditions. The 2001 study results indicate the benthic macroinvertebrate and fish communities in Toussaint Creek are in relatively poor condition (USACE 2002a). All sampling stations in Toussaint Creek, including two reference stations, were in non-attainment with Ohio Environmental Protection Agency (Ohio EPA) Warmwater Habitat (WWH) biocriteria. However, the results of this study indicate the release from the Luckey site is not the cause of the creek’s non-attainment with Ohio EPA WWH biocriteria. The results also indicate the release does not pose an unacceptable risk to ecological receptors. The results of the RI human health

risk assessment indicate chemical constituents released from the site do not pose an unacceptable risk to human health. Based on these conclusions, no further action is required for Toussaint Creek and select tributaries under FUSRAP. Thus, remedial alternatives are not evaluated for Toussaint Creek and select tributaries in this FS.

1.3 REPORT ORGANIZATION

The organization of this report is based on United States Environmental Protection Agency (EPA) guidance and includes nine major sections. Following this introduction in Section 1, Section 2 presents background information on the Luckey site including a brief account of site ownership, operations, and impacts. Section 3 outlines the development of RAOs for the constituents and media of concern. Section 4 reviews the identification and screening of technology types and process options considered for possible use in site remediation. Section 5 develops the proposed remedial alternatives, which are analyzed in detail in Section 6. Section 7 summarizes partnering and public involvement activities. Section 8 presents conclusions. References are found in Section 9, followed by the appendices. The appendices provide information supporting the evaluations presented in the body of this FS Report and include groundwater monitoring data, updated evaluations of subsistence farmer and industrial worker scenarios, volume estimations, a summary of waste disposal options, a site-specific transportation assessment, groundwater modeling of contaminant transport, and detailed cost estimates.

2.0 BACKGROUND INFORMATION

This section provides a general description of the Luckey site, including its environmental setting, historical uses, past activities that have or may have resulted in site contamination, and the results of previous environmental investigations. The information is summarized from the final *Remedial Investigation Report* for the Luckey site (USACE 2000a). For more detail on any of the subjects herein, consult the appropriate section of the RI Report.

The Luckey site is located at the corner of Gilbert and Luckey Roads at 21200 Luckey Road, northwest of the village of Luckey in Wood County, Ohio. The nearest large city is Toledo, Ohio, which is 22 miles to the northwest (Figure 2.1). The site property is approximately 40 acres in size (Figure 2.2). Various industrial activities have been conducted at the site since 1942. AEC-related beryllium production activities, and related operations occurred at the site from 1949 to 1961. This FS addresses the media impacted by AEC-related constituents. Other constituents detected at the site unrelated to AEC-related activities are considered only in terms of potential impacts to the remedial alternatives evaluated within this FS.

2.1 ENVIRONMENTAL SETTING

2.1.1 Climate and Land Use

The climate in Wood County is temperate. Average temperatures at Toledo range from a high of 83° F in July to a low of 30° F in January. Mean annual precipitation is 33 inches. Runoff is 10 inches per year and evapotranspiration is estimated at 22 to 24 inches per year (Harstine 1991 and Lyford and Cohen 1988).

The area is rural in character. The predominant local land use is agriculture, producing crops such as corn, soybeans, and winter wheat. Farm fields are found to the north, east, and west of the Luckey site. Patches of forests and old fields of varying ages dot the area. Just south of the site is the France Stone Company quarry. The quarry has been inactive since the early 1970s.

In rural areas, groundwater from the carbonate bedrock aquifer is the primary source for domestic supply. In general, residents in the vicinity of the Luckey site depend on wells drilled into this aquifer. Domestic supply wells are typically completed 50 to 80 feet (ft) into the carbonate bedrock aquifer and cased to approximately 30 ft below ground surface (bgs). Estimated daily per capita use is slightly less than 75 gallons (gal) per day for residents who depend upon private wells.

2.1.2 Geology

The topography of the area surrounding the Luckey site is flat and consists of shallow surface gradients sloping toward Lake Erie at a rate of approximately 3 to 4 ft/mile (Glaze 1972). Surface elevations at the Luckey site range from 647 to 664 ft above mean sea level amsl. The Luckey site is generally higher in the northeast corner due to past disposal activities. Other features include the village of Luckey (680 ft amsl); the inactive France Stone Quarry (estimated total depth of 70 ft); and Toussaint Creek (creek bed elevation of 634 ft amsl where it passes beneath Lemoyne Road).

The Luckey site sits on a mantle of glacial deposits overlying a sequence of relatively flat-lying sedimentary bedrock. The glacial deposits consist of soils (formed from weathering of the glacial deposits), glacial tills, and thin sand and gravel lenses. The clay-rich till often covers a pebbly till (Paulson 1981, USDA 1966, and Glaze 1972). Discontinuous or sporadic sand lenses occur within the clay-rich till. Sand and gravel deposits also occur immediately above the bedrock. All of the glacial

deposits (soils, clay-rich tills, sands and gravels) overlying the bedrock can be grouped together and termed unconsolidated overburden. At the Luckey site, the unconsolidated overburden ranges from 15 to 26 ft thick, gradually increasing in thickness to the north toward Toussaint Creek.

The predominant soils in the area, clays of the Hoytville series, are characterized by very poorly drained, dark-colored soils in fine-grained, gritty till on broad flats. While most of the Luckey site sits on Hoytville clay, a section near Lagoon C sits on Hoytville clay loam. These soils are almost identical, varying slightly in clay content. Surface infiltration in Hoytville soils is poor. The poor drainage, along with the generally flat topography, results in the need for a network of drainage ditches in the region. Agricultural fields in the area also are drained by a network of tiles discharging to drainage ditches in the region. Prior to the construction of such ditches, much of the former glacial lake plain was a swamp, known as the "Great Black Swamp." Results from geo-technical analyses classified most soils at the site as lean clay (CL) with some fine sand and silt. Soil acidity is relatively neutral, with a pH ranging from 6.4 to 7.1.

The uppermost bedrock, the Lockport Dolomite, ranges in thickness from 125 to 475 ft (Breen and Dumouchelle 1991). Oil well logs indicate the thickness of the dolomite to be 300 ft near the site. The Lockport Dolomite is massive in structure, open to vesicular in texture, light gray to bluish gray, generally poor in fossils, and granular or crystalline. The dolomite consists mainly of calcium-magnesium carbonate and, as a result, the Lockport Dolomite is also referred to as carbonate bedrock. The dolomite bedrock lies on a layer of Rochester Shale that is approximately 20 ft thick. Rochester Shale has a distinctive green color and often contains gray or greenish gray crinoidal dolomite. It is believed that this formation provides a fairly impermeable separation between the bedrock aquifer above and the units below.

2.1.3 Hydrogeology

Two water-bearing units are present in the vicinity of the Luckey site, one in the unconsolidated overburden and the other in the carbonate bedrock. In northwest Ohio, the thick sequence of Silurian and Devonian carbonate bedrock comprises a regional aquifer that serves as the primary source of groundwater for much of the rural population of Wood County. Groundwater within the Lockport Dolomite comprises the carbonate bedrock aquifer at the Luckey site.

The nearest private water supplies are domestic wells located at nearby residences (Figures 2.2 and 2.3). There are no nearby public water supplies. Residents of the village of Luckey, located south and up-gradient of the site, also rely on private domestic wells. There are no irrigation wells in the vicinity of the site.

The upper water-bearing unit in the overlying unconsolidated overburden consists of sand and gravel lenses within the till, but little information regarding water-yielding characteristics is available. Most of the glacial deposits in Wood County are poor water producers due to high clay and silt content (Smith and Sabol 1994). A weathered detrital or broken rock zone typically occurs above the competent bedrock. This zone is often saturated with groundwater and can be a good water supply for domestic use (Breen and Dumouchelle 1991 after Paulson 1981).

The carbonate bedrock aquifer is a good to excellent producer with typical yields of 10 to 20 gallons per minute (gal/min), and can reach 100 to 500 gal/min (Smith and Sabol 1994). The Lockport Dolomite supplies water from its entire thickness, but is usually tapped from 50 to 80 ft below the surface of the unit (Paulson 1981). Water bearing zones occur along joints, fractures, and solution openings in the carbonate bedrock aquifer. Wells completed at different depths within the bedrock were observed to have similar water levels, suggesting that these water-bearing zones are interconnected (Paulson 1981),

and therefore, groundwater flow along discrete fractures or solution openings is not significant in the upper 50 to 80 ft of the carbonate bedrock aquifer.

The general groundwater flow direction in Wood County is from recharge areas in the south to discharge zones at Lake Erie and the Maumee River. A potentiometric surface map compiled by Breen and Dumouchelle (1991) shows a groundwater mound beneath the village of Luckey. The mound is associated with the shallow bedrock and with higher recharge rates for this area. Radial groundwater flow occurs away from the mound in all directions, with the exception of limited flow toward the southwest. Lateral groundwater flow within the overlying clay-rich tills at the Luckey site is believed to be negligible.

Bedrock groundwater recharge occurs through several mechanisms. These include leakage of water from precipitation through the glacial till overlying the bedrock, direct infiltration of precipitation where the unconsolidated overburden is thin or absent, and infiltration of surface water through streambeds. Breen and Dumouchelle (1991) analyzed tritium in groundwater obtained from the carbonate bedrock aquifer in Lucas, Wood, and Sandusky Counties to identify areas where the groundwater is relatively young—i.e., recently recharged by infiltrating precipitation. Results indicated that areas where the till is 20 ft thick or less are where most of the recharge occurs. These include Bowling Green, Luckey, Stoney Ridge, and Pemberville (Smith and Sabol 1994). It appears that most recharge is occurring via the lateral flux of water from the south bedrock high at Luckey. Paulson (1981) noted that recharge to the carbonate bedrock aquifer occurred from November through May, with the most recharge occurring during May.

Since 1998, 38 monitoring wells have been installed at the Luckey site and in the farm field to the north. Monitoring wells were completed either as shallow (S) (in the unconsolidated overburden overlying bedrock), intermediate (I) (within the top 10 ft of bedrock), or deep (B) (greater than 20 ft beneath the top of bedrock). Water level data collected since 1998 have been used to construct well hydrographs, water table maps, and potentiometric surface maps (USACE 2002b). The hydrographs indicate groundwater elevations in the shallow, intermediate, and deep zones can vary significantly on a daily (up to 0.5 ft) and an annual (roughly 3 to 5 ft on average) basis. With the exception of two deep wells, average daily and annual fluctuations are similar regardless of the depth of the well.

The primary water-bearing zones in the unconsolidated overburden at the Luckey site are the relatively thin zones of sand and gravel at or near the bedrock interface. Due to the discontinuous nature of these zones, it is unlikely that they would be able to support sustained production of groundwater. The potentiometric surface in the shallow bedrock is very similar to the water table surface in the overburden through most of the site. Water levels from deeper bedrock wells indicate a downward gradient over the site. Groundwater discharge to Toussaint Creek is implied by the contours in the northeast portion of the Luckey site and has been verified by subsequent water level data and stream staff gauge data. Directly north of the site, groundwater levels are below creek stage levels during the summer and fall based upon data collected, thus the stream loses water to groundwater during these seasons.

Two groundwater production wells are located on the Luckey site. The West Production Well [PW(W)] and East Production Well [PW(E)], which has a totalizing flow meter, are capable of yields of 186 gal/min and 246 gal/min, respectively. Both wells are installed to a depth of 320 ft bgs. The well water is hard due to the calcium and magnesium-rich nature of the bedrock formation. The East Production Well currently is the primary water source for the facility and supplies groundwater at an estimated rate of 30 to 70 gal/min for the Uretch facility. Currently, the West Production Well primarily is used as a backup supply.

Two deep wells have been installed at or near the Luckey site: MW-34(B) and MW-39(B) (Figure 2.3). MW-34(B) is installed near the residence north of the site adjacent to well MW-33(I) in a very low yielding portion of the carbonate bedrock. During sampling efforts, the well is typically pumped dry and allowed to recover prior to sampling. Therefore, the responses seen in this well could be classified as muted when compared to the fluctuations observed in shallower wells at the site.

MW-39(B) is installed along the northern property boundary of the site adjacent to three other shallower wells, MW-01(I), MW-02(S), and MW-40(B). All three of the shallower wells exhibit similar trends and fluctuations in water levels and appear relatively unaffected by the operation of the East Production Well when compared to MW-39(B). Water levels in MW-39(B) do vary significantly in response to the operation of water levels in shallower wells. However, the East Production Well operates at a flow rate significantly greater than a domestic well.

The limestone quarry to the south of the Luckey site appears to act as a local source of groundwater recharge to the bedrock aquifer. Groundwater in the bedrock flows from the quarry northward toward the Luckey property. Drawdown from the East Production Well results in a large cone of depression in the unconsolidated overburden and captures most groundwater beneath and north of the facility. This cone of depression appears to periodically influence flow from Toussaint Creek into groundwater.

2.1.4 Surface Water

Surface drainage features at the Luckey site include several outfalls (permitted under the National Pollutant Discharge Elimination System [NPDES]), storm sewers, drainage ditches, and wetland areas. On-site discharge sources flow into two main channels, the main drainage ditch and the western drainage ditch. These drainage ditches ultimately empty into Toussaint Creek located north of the Luckey site (Figure 2.3). Toussaint Creek eventually empties into Lake Erie approximately 25 miles downstream.

The main drainage ditch originates southeast of the Annex and converges with various flows just east of Lagoon D. The main drainage ditch is approximately 10 ft wide and 395 ft long (on site). It courses northward and crosses an agricultural field before emptying into Toussaint Creek. Runoff from roof drains and truck bays at the Production Building, Annex, and other buildings discharges to the main drainage ditch. In addition, sanitary drains convey waste water from the on-site buildings to the sewage treatment plant. Treated effluent is subsequently discharged to the main drainage ditch at an NPDES outfall near the filter beds.

The western drainage ditch (also known as the Luckey Road ditch) runs along Luckey Road at the western property boundary, flows northward, and also empties into Toussaint Creek. Runoff from on-site drainage features discharges to the ditch at three locations. The southernmost point, NPDES Outfall 004, receives stormwater from roof drains at the former Laboratory Building and the Annex. This flow is conveyed to the western drainage ditch in an open concrete-lined ditch. A second discharge point, NPDES Outfall 006, is located between Outfall 004 and the Plant entrance. This outfall receives stormwater runoff from asphalt driveways and possibly from the roof drains of the Main Office Building via another concrete-lined ditch. The northernmost outfall is a drainage pipe from the former lime pit, which emptied into the ditch near the northern property boundary.

The USACE reported the presence of one wetland subject to federal jurisdiction under Section 404 of the Clean Water Act at the time it was delineated on the Luckey site north of Lagoon C and east of Lagoon D (USACE 1998a). This is a shallow emergent wetland approximately 1.6 acres in size. Due to its isolation from navigable waters, this wetland is no longer subject to federal jurisdiction. However, any dredge or fill activities in this wetland would meet the substantive requirements of a State of Ohio

isolated-wetland fill permit in order to comply with Clean Water Act, Section 401 requirements in Ohio as amended by Ohio House Bill 231. The main drainage ditch immediately east of the pump house and filter beds also meets the definition of a shallow emergent wetland and is subject to federal jurisdiction. This wetland is connected to navigable waters, and as such, remains subject to requirements of Section 404 of the Clean Water Act.

2.2 SITE HISTORY

2.2.1 Site Ownership

In 1942, the Defense Plant Corporation (DPC) built a magnesium reduction plant at the Luckey site to produce metallic magnesium. The plant ceased magnesium operations in November of 1945. Past magnesium operations and subsequent impacts to the environment are outside the scope of FUSRAP and the Luckey site RI/FS.

The Luckey facility was transferred to the Reconstruction Finance Corporation in 1945. As early as 1946, Brush Beryllium Company (BBC), as a contractor to the AEC, was allowed to use equipment from the Luckey plant in pilot projects. In late 1948, fire destroyed most of BBC's Lorain plant. As a result, BBC was not able to complete work contracted by AEC. Accordingly in 1949, BBC entered into a contract with the AEC to build and operate a replacement facility. BBC designed, constructed, and began to operate a plant for the production of beryllium. The beryllium production facilities were owned by AEC and operated by BBC from 1949 to 1958.

The Luckey plant produced mostly beryllium hydroxide (Powers 1983), as well as some beryllium metal in vacuum-cast billets and beryllium oxide (from beryllium hydroxide). Some of the beryllium hydroxide was used to make beryllium copper alloys at another location. Sintering and powder blending operations began in 1957 and continued into the early 1960s.

In 1959, the AEC contracted BBC to close the facility at the Luckey site. An on-site disposal area was designated in the northeastern corner of the property and plans for decontamination were developed. Although building decontamination plans are documented, no subsequent documentation was found to indicate AEC actually implemented decontamination.

In 1961, the General Services Administration sold the site to the privately owned Aluminum and Magnesium, Inc. The government retained access rights in order to remove any remaining beryllium ore. In 1962, Luckey Industries, Inc. purchased the former beryllium facility, hoping to reclaim magnesium from World War II incendiary bombs. The reclamation process was unsuccessful and the property reverted back to Aluminum and Magnesium, Inc. The facility then was used to recover zinc from by-products of the steel industry. In 1967, Aluminum and Magnesium, Inc. transferred the property to its parent company, the Vulcan Materials Company.

In 1968, the Goodyear Tire and Rubber Company purchased the site and began producing automotive foam seating and other urethane products. In 1983, Motor Wheel Company leased the property from Goodyear, later purchasing it in 1988. Motor Wheel used the site to coat steel automotive wheels with polyurethane foam and for other automotive products. Hayes Lemmerz International, Inc. is the successor company to Motor Wheel and is the current owner of the site. Since 1995, Hayes Lemmerz International, Inc. has leased about 23 acres of the site to Uretech International, Inc., which manufactures urethane parts for the automotive, sporting goods, and health care industries.

2.2.2 Previous Site Investigations

2.2.2.1 Preliminary Radiological Survey and Preliminary Site Evaluation

The Oak Ridge National Laboratory (ORNL) conducted a preliminary radiological survey of the Luckey site in December 1988. This study involved gamma walkover surveys over a large portion of the property, as well as the collection of surface and subsurface soil and water samples (ORNL 1990). The walkover surveys were performed using a portable gamma-scintillation meter. Gamma exposure rates over the majority of the property ranged from 5 to 9 microRoentgen per hour ($\mu\text{R/h}$). Instances of elevated radioactivity ($800 \mu\text{R/h}$, up to a maximum observed value of $1,500 \mu\text{R/h}$) also were observed in the lagoon and landfill areas, near the propane tanks, and at other isolated locations. Seven stations had radium-226 activities above 100 picocuries per gram (pCi/g). The highest beryllium concentrations were found at Lagoon B at 6,400 milligrams per kilogram (mg/kg). Elevated beryllium concentrations also were detected at Lagoons A and C and in the farm field north of the site.

In 1996, a preliminary site evaluation was performed to further evaluate site characteristics and locations of potential contamination. The evaluation concluded that there might be an unacceptable risk to potential receptors at the site and recommended that further investigation be conducted to thoroughly evaluate risks to human health and ecological receptors (DOE 1996).

2.2.2.2 Remedial Investigation

A RI was initiated for the Luckey site in 1996 to determine the nature and extent of constituents and to evaluate the risks to human health and the environment in a risk assessment. The RI was completed in four phases. Results are documented in the final *Remedial Investigation Report* for the Luckey site (USACE 2000a) and summarized in Section 2.3 of this FS.

Phase I

After designation of the Luckey site into FUSRAP, DOE initiated Phase I, the initial planning for the RI, in 1996. This consisted of record searches and the development of a sampling and analysis plan (SAP) for the initial field investigation activities. The overall goal of the RI was developed and stated in site-specific data quality objectives (DQOs), which were included in the SAP (DOE 1997).

Phases II and III

DOE initiated Phase II site characterization fieldwork in 1997; however, in October of 1997 Congress gave management of the FUSRAP program to USACE. USACE directed implementation of subsequent investigations and activities at the Luckey site. Phase II sampling activities were primarily non-intrusive. Work elements included site-wide reconnaissance surveys for beryllium and radiological activity; soil, sediment, and surface water sampling; background gamma exposure sampling; air sampling; radiological walkover surveys; building radiological surveys; a scoping survey in the Annex; surface geophysical surveys; and downstream sediment sampling from Toussaint Creek.

Results from that effort are documented in the *Phase II Characterization Report for the Luckey Site* (USACE 1998b). Phase III assessed the data collected during Phase II. The results were then used to plan more intensive Phase IV RI activities.

Phase IV

The Phase IV RI at the Luckey site was performed from 1998 to 1999 in accordance with the RI/FS Work Plan and Addenda (USACE 1998c, 1999c). Fieldwork included extensive sampling of soil, sediments, surface water, groundwater, and tap water both on site and off site. A radiological walkover survey was conducted on adjacent properties. Swipe and dust samples also were taken inside buildings.

In 1998, the USACE also performed a wetlands designation survey in accordance with guidance in the *Wetland Delineation Manual* (USACE 1987). The results of the survey are summarized in Section 2.1.4 of this FS and documented in the *Wetland Delineation Report for the Luckey Site* (USACE 1998a).

Groundwater Model Report and Addendum (USACE 2001a, USACE 2002b)

These reports present the site-specific groundwater model developed for the Luckey site. The reports include input parameters used to develop the model, water level maps for both the overburden and bedrock units, and results of analyses of predicted water levels and flow patterns under pumping and non-pumping conditions (i.e. impact of operation of the East Production Well). The groundwater model was subsequently used to simulate transport scenarios in support of this FS.

Toussaint Creek Bioassessment

In the RI Report for the Luckey site (USACE 2000a), possible impacts from the release of constituents to adjacent waterways, primarily Toussaint Creek, were investigated. This investigation included chemical analysis of sediment and surface water and an evaluation of the benthic macroinvertebrate community and habitat quality using EPA's Rapid Bioassessment Protocol. Qualitative conclusions from this investigation contained uncertainties that prevented a final resolution for the site. These uncertainties included the lack of toxicity data for beryllium, the overall poor habitat quality in the creek, and the role of other outfalls (e.g., sewage) on stream biota. Discussions with Ohio EPA concerning these uncertainties resulted in the derivation of the additional studies using Ohio EPA's protocols for bioassessment of surface waters. The additional work was designed to provide sufficient rationale for the final decisions concerning whether or not a remedial action is warranted in Toussaint Creek and unnamed tributaries within the Luckey RI/FS framework. The work plan was finalized in the spring of 2001 and the field work was conducted in June and August, 2001. The results and conclusions of these additional studies are contained in the *Biological and Water Quality Study of Toussaint Creek and Select Tributaries in Support of the Luckey Site Remedial Investigation/Feasibility Study* (USACE 2002a). A summary of results is presented in Section 2.4.2 of this FS.

2.2.2.3 Other Investigations

There are, or are reported to be, other historical data which may be useful in the evaluation of the Luckey site. Some of this information dates back to the 1940s and 1950s and is incomplete. The following summarizes these investigations and pertinent results:

- In 1949, the Ohio Department of Health (Ohio DOH) approved the use of the lagoons and required groundwater and surface water monitoring (Ohio DOH 1949). No records from this monitoring have been located.
- Connectivity of the lagoons with groundwater was tested in shallow wells in December 1953. Wells were drilled to a depth of 20 ft. Records are available for pH, sulfate, and ammonia for three sample events (Schwenzfeier 1956). All the wells were dry except for one on the southeast corner of the "solar evaporation lagoon," which is assumed to be Lagoon C.

Sulfate and beryllium results in the shallow well water indicated some connectivity, but the absence of water in most wells was interpreted as an indication that little percolation was occurring (Schwenzfeier 1954).

- In response to concerns about potential groundwater contamination at the National Gypsum Company quarry (current France Stone quarry) due to prior activities at the Luckey site, pH, sulfate, beryllium, and ammonia were sampled from lagoon waste water, Toussaint Creek (upstream and downstream of the discharge), the Luckey plant “deep well” (whether this was the east or west well is unclear), off-site farm wells, and National Gypsum quarry water (Schaffner 1954). Concentrations of beryllium in most samples were at or below 0.25 parts per million (ppm). A radioactive iodine tracer was released into the lagoons to see if a hydrologic connection could be demonstrated. No documented results have been found; however, subsequent correspondence indicates that magnesium sludge in the Troy Township Dump may have been the source of the groundwater contamination at National Gypsum (Schwenzfeier 1956).
- Other wells have been sampled on and around the Luckey property. Potable water analyses from the Luckey facility exist for 1985 to 1990, with individual reports extending into the 1990s. Results show that beryllium in the potable water generally has been below detectable concentrations and/or below the Safe Drinking Water Act (SDWA) maximum contaminant level (MCL) of 4 micrograms per liter ($\mu\text{g/L}$). There were some exceptions in late 1985/early 1986 when beryllium was detected at concentrations up to 8.8 $\mu\text{g/L}$ (MASI 1986), although this was prior to the establishment of the MCL.
- In January 2001, groundwater samples were collected from residential wells located in the vicinity of the Luckey site. Sampling activities were sponsored by USACE in conjunction with the Wood County Health Department. Groundwater samples were analyzed for beryllium, manganese, and total uranium. Beryllium was not detected in any of the groundwater samples. Neither manganese nor total uranium were detected above drinking water standards (50 $\mu\text{g/L}$ and 30 $\mu\text{g/L}$, respectively). Manganese was detected at concentrations ranging from 0.54 to 31.2 $\mu\text{g/L}$. Total uranium was detected at concentrations ranging from 0.02 to 14.0 $\mu\text{g/L}$. Average concentrations were 6.1 $\mu\text{g/L}$ for manganese and 3.39 $\mu\text{g/L}$ for total uranium.

2.3 SITE CHARACTERIZATION

The Luckey site is comprised of a large production building and warehouse, two abandoned railroad spurs, and several smaller process and ancillary buildings. The area surrounding the site to the west, north, and east is primarily residential farmland. An abandoned railroad bed runs along the eastern boundary. A former quarry (France Stone Quarry) and municipal dump (Troy Township Dump) border the site to the south and southeast, respectively (Figure 2.2). Site features are depicted in Figure 2.4. Four disposal trenches (trenches 1 through 4) are located in the northeast corner of the site. This area also is referred to as the disposal area. Two trenches (5 and 6) occur west of trenches 1 through 4. Trench 7 is located south of trenches 1 through 4. Three lagoons occur in the southeastern portion of the property. The former ore staging and spoils areas were located south and west of the filter beds. There is a former lime pit or settling basin for the water treatment facility located north of the on-site buildings and partially covered by the current parking lot. There also is a former scrap steel storage area located alongside the railroad spur north of the maintenance and bulk storage buildings. In the western portion of the site is a cistern filled with crushed brick (reportedly from the main stack). Several areas devoid of vegetation also are identified in Figure 2.4.

2.3.1 Source Media

Source media at the Luckey site include the source materials brought to the site for processing or reprocessing. These materials included:

- Beryl ore from Africa and South America, shipped in bags and barrels via rail
- Some scrap beryllium sent for reprocessing, shipped by truck
- Contaminated scrap iron sent for possible reprocessing, shipped by rail car.

2.3.1.1 Beryl Ore and Beryllium Scrap

According to employee interviews, beryl ore, purchased from brokers or the AEC, arrived at the Luckey site in bags and drums. The ore particles varied in size from large pieces (the size of half a brick) to small gravel-size particles that appeared to have been crushed prior to shipment (Cline 1990). Ore was stored on both sides of the railroad siding near the railroad scales (Singleton 1990) and on roadways adjacent to the production buildings (Ohio EPA 1997).

Ground beryl ore also was obtained from the former Middlesex Sampling Plant in Middlesex, New Jersey (another AEC facility). The rock grinders that crushed the beryl ore also were used to grind uranium ores. The beryl ore may have acquired radiological constituents left behind by the uranium grinding operations (DOE 1991b). Pegmatites containing beryl ore obtained from South America also may have contained small amounts of naturally occurring radionuclides.

Records also indicate that beryllium scrap from other AEC operations was being sent to Luckey for reprocessing. Indications are that some of this scrap was contaminated with radionuclides (Smith 1950). At least one shipment of such scrap contained uranium as the primary contaminant. The Luckey process was well suited for reprocessing, since feed material was dissolved in acid to initiate the process. At successive stages contaminants were either precipitated or decanted.

2.3.1.2 Contaminated Steel Scrap

Records indicate that in late 1951, the Luckey site received approximately 1,000 tons of scrap steel from the Lake Ontario Storage Area (LOSA). The steel, reportedly intended to control chlorine gas as a by-product of the magnesium production process, consisted primarily of used, empty steel drums containing radioactive residues (TAPR 1951). Employee interviews, however, indicate the scrap was to be used in setting up the beryllium production process. The scrap steel was delivered by railroad between December 1951 and early 1952. It was stored in the yard north of the main building along the railroad tracks. Only a small portion of the steel was usable by BBC. Some of the scrap metal may have been sold to local scrap dealers (Cline 1990).

2.3.2 Historical Operations

Beryllium production activities and operations at the Luckey site are summarized in Table 2.1. Beryllium production operations occurred from 1950 to 1958. Site closure activities were initiated in 1959 and the facility was sold in 1961. A pictorial summary of historical operations is presented in Figure 2.5.

The primary location of beryllium processing was the Annex on the south side of the Production Building. In the Annex, beryllium ore was first converted to beryllium oxides and then to beryllium metal. South of the Annex are three lagoons. Process wastes were discharged to the lagoons in liquid or slurry form. Liquids from the lagoons were reportedly evaporated during dry weather, but discharged to

the ditches and Toussaint Creek during periods of high rainfall. Fluids from Lagoon A flowed west-northwest to the ditch along Luckey Road before flowing north to Toussaint Creek. Fluids from Lagoons B and C flowed into the main drainage ditch that flows north from the site to Toussaint Creek. During summers from 1950 through 1958, sludge from the lagoons was dredged, transported, and discharged to disposal pits and trenches located in the northeast corner of the property.

In 1959, AEC contracted with BBC to close the Luckey plant and site closure activities were initiated. An on-site disposal area was designated in the northeastern corner of the property. Some eight acres were set aside, although only two actually were used. Plans for decontamination of the buildings included dismantling/disposing process equipment and steam cleaning building interiors. Decontamination plans emphasized thorough cleaning and painting (using a silicone preparation) to reduce exposure to beryllium. Although building decontamination plans are documented, no subsequent documentation was found to indicate AEC actually implemented decontamination. Process piping and ventilation ducts in the beryllium wing (i.e. Annex) were dismantled and are reported to have been sent to Oak Ridge, Tennessee or disposed on site. The AEC suggested that bricks from the demolition of the smokestack be disposed on site and that the lagoons be drained and covered. The large sintering furnace was eventually removed and taken off site.

Following closure, the lagoons were reportedly covered with 3 to 5 ft of clean soil. The surrounding dikes and embankments were later used to fill the lagoons (Cline 1990). Lagoon C was reported to have been capped immediately. Lagoons A and B were later covered with a 2-ft thick clay cap to hinder wind dispersal of dust (Knutsen 1988). Sampling conducted by ORNL in 1988 indicated the sludge might not have been completely removed from all three lagoons (ORNL 1990). For example, some data indicate Lagoon C was covered with clean fill but was not excavated prior to being covered (DOE 1991b).

2.3.3 Impacted Media

Sampling activities focused on site features associated with beryllium production processes and disposal operations at the site. This section summarizes information presented in the RI on site features and known nature and extent of contamination observed in impacted soils and groundwater. Tables 2.2 and 2.3 summarize analytical data for AEC-related constituents detected in impacted soils and groundwater.

2.3.3.1 Impacted Soils

Impacted soils were investigated by focusing on features known or believed to have been impacted by past AEC activities at the site (Figures 2.4 and 2.5). These features include:

- trenches and pits (disposal areas)
- lagoons
- bare spots and stressed vegetation areas
- filter bed area and debris piles
- soil around existing buildings and associated areas
- off-site soils (surrounding property).

Trenches and Pits (Disposal Areas)

The northeast corner of the Luckey site was used as a disposal area for lagoon sludges, scrap metal, and other waste materials (Figure 2.4). There were at least four sludge disposal trenches (trenches 1 through 4) in addition to scrap pits and piles of building debris. The sludge disposal trenches were

reported to be 14 ft wide by 18 ft deep. Each summer from 1950 through 1958, sludge from the lagoons was dredged, transported, and disposed in the disposal pits and trenches located in the northeast corner of the property. The spoils mounds consisted of excavated soil, process materials, and ores. At closure, all pits and trenches were reportedly covered with 4 ft of clay and marked (Singleton 1990).

Two and perhaps three additional disposal trenches (trenches 5 through 7) were dug and are reported to have received scrap steel and cracked graphite crucibles containing beryllium fluoride and magnesium fluoride. Vehicles were reportedly buried in the last trench, which was dug during closure. The trenches were reportedly dug to an estimated depth of 6 ft although one scrap metal trench was found to be 12 ft deep. Soil from the excavation was used to cover the trenches after they were full.

Two inorganics (beryllium and lead) and five radionuclides (radium-226, thorium-230, thorium-234, uranium-233/234, and Uranium-238) were the most commonly detected AEC-related constituents above background in soil samples from the disposal trenches and pits (Table 2.2). Detections above background at depths greater than a few feet were generally encountered within and beneath the trench and pit fill materials. Contamination between the trenches and pits is generally confined to the surface soils.

Lagoons

Four waste lagoons (labeled A, B, C, and D) were constructed in the southeast portion of the Luckey site. The lagoons were shallow and were created by scraping off the top layer of soil and building an embankment. Liners were reported to have been compacted clay.

Lagoon A was 3 to 4 ft deep and received waste from the conversion of beryllium hydroxide to beryllium metal. Beryllium hydroxide was dissolved in ammonium bifluoride solution to form an ammonium beryllium fluoride solution. Calcium carbonate, lead oxide, and sulfides were then added to precipitate impurities, which were filtered and pumped to Lagoon A. Magnesium fluoride was removed by rinsing with water, and the magnesium fluoride solution was discarded to Lagoon A. The solution also contained ammonium fluoride, ammonium sulfide, and beryllium fluoride. Lagoon A discharged to the western drainage ditch. Lagoons A and B appear to have been in use simultaneously.

Lagoon B (5 to 6 ft deep) and Lagoon C (1 to 1.5 ft deep) received discharges from the conversion of beryl ore (beryllium aluminum silicate) to beryllium hydroxide by the sulfate process. Beryllium sulfate, aluminum sulfate, and silica were formed from the ore. Sulfates, silica, ammonium alum, and iron cake were removed and discarded. Waste solutions contained high levels of dissolved solids, primarily sodium sulfate and sodium hydroxide. Conversion of beryllium hydroxide to beryllium oxide resulted in a scrubber sludge of sulfur oxides, which were discharged to Lagoons B and C (Powers 1983), which themselves discharged to the main drainage ditch. Lagoon C was the largest and shallowest of the three lagoons. A fourth lagoon, Lagoon D, is noted north of Lagoon C, but apparently was not used.

Two inorganics (beryllium and lead) and four radionuclides (radium-226, thorium-234, uranium-233/234, and uranium-238) were the most commonly detected AEC-related constituents above background in soil samples from the lagoons (Table 2.2). Lead, which was used as part of the beryllium refining process, was detected above background in 14 of 55 soil samples collected from Lagoons A, B, C, and D. Eight of these were detected in soil samples from Lagoon C. The radionuclides appear to be primarily associated with soils at Lagoon B.

Bare Spots and Stressed Vegetation Areas

Areas either lacking vegetation or displaying stressed vegetation are located in the north-central portion of the facility near the propane tanks and in the northeastern section of the site near the trenches. A number of constituents were detected above background in soils of the bare spot and stressed vegetation areas. These included beryllium, lead, and radionuclides (thorium-228, thorium-232, and uranium-234) (Table 2.2). A weight-of-evidence analysis compared surface soil concentrations of constituents to field observations of stressed vegetation. Elevated concentrations of beryllium and lead were found to be collocated with areas devoid of vegetation. Past practices also may have affected the soil structure in these areas and some areas exhibit unusual accumulations of coarse material.

Filter Bed Area and Debris Piles

At the filter bed area and debris piles, beryllium and lead were the metals most commonly detected above background. Five radionuclides (radium-226, thorium-230, thorium-234, uranium-233/234, and uranium-238) also were detected above background.

Existing Buildings and Associated Areas

Around the existing buildings, beryllium and lead were most commonly detected above background. Three radionuclides (thorium-232, thorium-234, and uranium-235) were detected in the soils at concentrations slightly exceeding background. Beryllium concentrations were significantly less than other areas on site (Table 2.2).

Off-Site Soils

The Luckey site is surrounded on three sides by open agricultural land used primarily for crop production. Impacts to off-site soils might have resulted from run-off and airborne constituents released from the site. Contamination from these mechanisms is expected to be isolated in the upper 2 ft of soil. Farming activities such as plowing and tilling may have mobilized surface-deposited constituents and diluted them in the shallow soil matrix.

The northern farm field and the railroad track area appear to have been impacted by releases from the Luckey site. Elevated constituent concentrations (primarily beryllium and lead) were found in the northern farm field along the main drainage ditch that flows north toward Toussaint Creek and along the northern property boundary of the Luckey site. Constituents along the ditch may have resulted from dredging and dumping the spoils along the ditch. Constituents along the northern property boundary may have resulted from windblown deposits or storm water runoff from the Luckey site.

Beryllium and radionuclides were detected in soils just east of the site in the vicinity of the former railroad tracks. The highest concentrations of beryllium and radionuclides were detected in the same three samples from borings located in the low-lying area between the roadbed and the Luckey site property boundary. They are located just east of the waste disposal trenches at the northeast corner of the site. Constituents may have been deposited there by wind blowing across the bare areas at the disposal trenches or from storm water runoff that collects in the low-lying area. The contamination in these two areas is contiguous with the on-site contamination.

2.3.3.2 Impacted Groundwater

Groundwater samples have been collected from the on-site and off-site monitoring wells (Figure 2.4) since they were installed in 1998. Validated analytical data collected during the Phase IV RI (1998 and 1999) are presented in Appendix 4A of the RI Report (USACE 2000a). Sampling was conducted in 2000, 2001, and 2002, subsequent to the RI field investigation. Validated analytical data collected during these sampling activities are included in Appendix 2A of this FS. Unfiltered (total) and filtered sample data are presented in these Appendices for metals and radioactive constituents. Generally, detections in filtered concentrations were lower or similar to the detections in unfiltered concentrations. Table 2.3 summarizes analytical data collected from the monitoring wells of interest.

Beryllium, lead, and uranium were detected above drinking water standards in groundwater samples collected from several monitoring wells. With the exception of the West Production Well, the exceedances occurred in groundwater encountered immediately above bedrock or in the shallow bedrock. Beryllium was the only constituent detected above drinking water standards in the West Production Well. There is little apparent seasonal variation in constituent concentrations collected between the summer of 1998 and the spring of 2000. More recent data (e.g. fall 2000 through spring 2002), however, indicate a seasonal variation. Together, this information suggests a relationship between water levels and constituent concentrations: as groundwater levels rise, higher concentrations of AEC-related constituents are generally observed relative to concentrations observed in preceding samples collected when water levels were lower.

Water levels measured in June 2001 were the highest recorded at the site. Water levels were measured above the reported base of several trenches in the northeast portion of the site. The reported base of the trenches are generally several feet deeper than depths indicated by soil boring data collected during the RI. Based upon reported depths, materials in the trenches would have been below the June 2001 water levels, while materials at depths indicated by soil boring data would have been in close proximity to June 2001 water levels. June 2001 water levels also are at an elevation near the former base of Lagoon B, five to six ft deep bgs. In both cases, groundwater could be in direct contact with contaminated materials resulting in a localized impact to groundwater (i.e. a “pulse” of contaminated groundwater) beneath these features. Because of the depth of the trenches, periodic wetting of materials in the trenches or in a “smear zone” beneath the trenches may occur with seasonal high groundwater levels. In the case of Lagoon B, this process was likely much more significant while the lagoon was in operation. The apparent relationship between higher groundwater levels and constituent concentrations also suggests groundwater periodically contacts constituents in a “smear zone” created by seasonal water level fluctuations during constituent transport. Examples illustrating this relationship are discussed below.

Beryllium has been consistently detected above the drinking water standard (4 µg/L) in monitoring wells MW-01(I), MW-02(S), and the West Production Well. All three samples obtained from MW-26(S) also exhibited elevated beryllium concentrations. Beryllium was detected in a filtered sample from MW-26(S) at 137 µg/L in June 2001, the highest result obtained thus far. MW-26(S) had not been previously sampled because the well was “dry.”

Figures 2.6 and 2.7 are included to illustrate trends between measured water levels and beryllium concentrations in monitoring wells MW-01(I) and MW-02(S), respectively. MW-01(I) is screened five to 10 ft into the carbonate bedrock. MW-02(S) is screened across the overburden-bedrock interface, which means the well is open to groundwater in both the overburden and the upper few feet of bedrock. Both show a slight trend in decreasing beryllium concentrations between the 1998 and early 2000 sampling events. This trend appears to mimic an overall trend in decreasing water levels for the same period. The lowest beryllium concentrations coincide with relatively low water levels observed in late spring 2000. In

June 2001, measured water levels at the site were the highest on record. Beryllium concentrations in MW-01(I) returned to concentrations similar to those measured in 1998 and early 1999. In MW-02(S), the highest beryllium concentration occurred at the same time as the highest measured water level and increased by a rough factor of five over measurements made in 1998 and early 1999. By November 2001, beryllium concentrations dropped significantly but were still above concentrations observed in 1998 through late spring 2000 by a rough factor of two. The observations suggest the intervals immediately above and within the first few feet of bedrock reflect the impact of periodic wetting of materials within or below the trenches. It also suggests these impacts are substantially attenuated within depths of five to 10 ft below the top of bedrock.

Other locations where beryllium was detected include three samples obtained from MW-26(S), completed immediately above the bedrock, which show a similar response to MW-02(S). Monitoring wells MW-01(I), MW-02(S), and MW-26(S) are located in close proximity to trench 5 (Figure 2.4). Two other wells, MW-13(S) and MW-19(I), located near the north end of trenches 2 and 4 did not show similar responses for beryllium. Beryllium was detected below the drinking water standard in all samples collected from MW-13(S). In MW-19(I), beryllium was detected slightly above the drinking water standard in four of the seven unfiltered samples, but was below the drinking water standard in all eight of the filtered samples collected from MW-19(I). Thus, materials within or beneath trench 5 appear to be a more likely source for the observed groundwater contamination in monitoring wells MW-01(I), MW-02(S), and MW-26(S), while trenches 2 and 4 do not appear to be significant sources of beryllium in groundwater.

Trends similar to those observed for beryllium also occur within the lead and uranium data. Lead was consistently detected above the drinking water standard (15 µg/L) in MW-21(I) with a maximum detected value of 46.2 µg/L. Lead concentrations (Figure 2.8) in MW-21(I) generally exhibited a decreasing trend in both unfiltered (total) and filtered samples until June 2001 when the maximum concentration was measured. By November 2001, lead concentrations had dropped to concentrations below those reported in 1998 and early 1999, indicating an overall slight decreasing trend. MW-24(S) showed very little, if any, changes in lead concentrations from 1998 to 2001. A concentration of 15.9 µg/L was detected in one of seven filtered samples. Lead was detected in an unfiltered sample at 15.3 µg/L; however, the filtered counterpart was below the drinking water standard.

Total uranium was consistently detected above the drinking water standard (30 µg/L) in MW-24(S) with a maximum detected value of 390 µg/L (converted from uranium-238 picocuries per liter (pCi/L) result). Like MW-02(S), MW-24(S) is completed across the overburden-bedrock interface. As shown in Figure 2.9, total uranium concentrations indicate a decreasing trend, even with observed seasonal variations. Total uranium has been detected above the drinking water standard in two samples collected from MW-21(I).

Operation of the two onsite production wells exerts a significant influence on groundwater flow beneath the Luckey site and, therefore, also exerts influence over the migration of contaminants within the groundwater beneath the site. As noted previously, the East Production Well is the primary production well currently in use at the site. Under pumping conditions, the cone of influence of the East Production Well (at estimated 70 gal/min) creates flow towards the well from all areas onsite and from much of the area beneath the farm field north of the site. Only limited data exists for water levels at the site when the East Production Well has been shutdown. However, modeling results indicate flow patterns to the north of the site consistent with regional flow trends published in literature. Constituents in the groundwater are therefore migrating towards the East Production Well when the well is pumping or to the north when the well is not pumping.

2.3.4 Contaminant Transport and Fate

This section summarizes factors influencing the potential movement of contaminants in the environment.

2.3.4.1 Transport Mechanisms

Figure 2.10 illustrates a conceptual model of contaminant transport mechanisms at the Luckey site. Mechanisms include wind transport, surface erosion and runoff, leaching from soils to groundwater, and transport within groundwater.

Materials released from site smokestacks were transported by the movement of air. These included flue gases containing sulfur oxides. Airborne releases were generally deposited on the soil through fallout and precipitation. Surface erosion and runoff potentially moves contaminants from the soil to drainage ditches, and from there northward to Toussaint Creek. Waste constituents have also been emplaced at depth or migrated vertically, via infiltration, from the base of the lagoons and waste disposal locations (trenches) resulting in deeper contamination than airborne emissions. Direct contact of groundwater with materials in the base of the disposal trenches and with materials beneath Lagoon B also may contribute to groundwater contamination. Based on sampling results, surface runoff/erosion and direct contact between groundwater and contaminated materials appear to represent active transport mechanisms. Leaching from the soils (clay-rich tills) and wind transport do not appear to be as significant.

Transport of contaminants in groundwater is a potential pathway off-site, but appears to be slowed or prevented due to the influence of the East Production Well and sorption within the clay-rich tills. Transport in groundwater is a complex process. Constituents in groundwater are affected by a variety of processes including advection, dispersion, dilution, oxidation-reduction potential, groundwater pH, and sorption. A groundwater flow model has been developed and calibrated for the Luckey site (USACE 2001a) and is used to evaluate the potential transport of constituents in groundwater (Appendix 6A).

Soil properties also affect the movement of contaminants. The most important properties are infiltration capacity, permeability, cation exchange capacity, and organic carbon content. Infiltration rate and permeability control the rate of movement of a liquid (or gas) through the soil. Both are low for the Hoytville Clay soils due to their density and high clay content. Cation exchange capacity and organic carbon content are chemical properties that affect contaminant migration by chemically interacting and binding with dissolved constituents as they percolate through the soil. These processes can be referred to as sorption. Soils with high clay content generally have higher sorption capacities than either sands and gravels or the carbonate bedrock.

2.3.4.2 Contaminant Fate

Many factors also affect contaminant fate. The form and characteristics of a contaminant will affect its behavior in the environment. Among these physical/chemical characteristics are solubility, adsorption, fixation, partitioning, volatilization, natural degradation, bioaccumulation, and decay (for radionuclides).

The metals and radionuclides at the Luckey site are cations and generally have limited mobility in soil and groundwater due to sorption onto the surface of mineral grains. Cationic metals tend to form stable and immobile oxides, hydroxides, carbonates, or phosphates under the neutral to alkaline pH conditions present at the site. For example, beryllium forms stable compounds with anions and beryllium

oxides and hydroxides generally have low solubility. Much of the beryllium at the Luckey site may be adsorbed onto mineral surfaces or may have formed complexes of insoluble compounds. In addition, radioactive materials decay naturally at known rates, depending upon the particular isotope.

2.3.5 Other Constituents

Under FUSRAP, the USACE is authorized to address only those constituents originating from AEC work or through other stipulations expressly stated in a site designation letter. At the Luckey site, these constituents include beryllium, materials associated with the beryllium production process (e.g., lead), and radioactive residuals. The natural source of beryllium is pegmatite and other hydrothermal beryllium ores. These also can contain arsenic. The barium is likely related to sulfides/sulfates used in the beryllium production process, as well as the pegmatite. Lead oxide was an additive in the beryllium production process. Activities and operations at the site subsequent to AEC activities may have resulted in impacts to the environment. While these impacts and related constituents are not under the purview of USACE at the Luckey site, these constituents may be collocated with AEC-related constituents. The characterization of non-AEC indicator compounds during the RI was limited to areas where beryllium or radionuclides were thought to be above acceptable limits. The nature and extent of these constituents is summarized below, in order to subsequently take into consideration potential constraints on technologies, alternatives, and disposal options.

In addition to AEC-related constituents (arsenic, barium, beryllium, lead, and radionuclides), other metals, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), semi-volatile organic compounds (SVOCs), volatile organic compounds (VOCs), and total recoverable petroleum hydrocarbons (TRPH) were detected in soils and groundwater at the Luckey site. Cadmium and PAHs were detected in soils collected from the trenches, lagoons, spoils piles, and around the buildings. SVOCs and VOCs also were detected, but generally at low concentrations. TRPH was detected in soils at former petroleum handling buildings and a former underground storage tank (UST) location. The PCB (Aroclor 1254) and TRPH were detected in the shallow surface soils associated with the former Transformer Room and electrical substation. Manganese frequently was detected in groundwater and was identified as a preliminary constituent of concern (COC) in the Baseline Risk Assessment (BRA) performed in the RI Report (USACE 2000a).

2.4 BASELINE RISK ASSESSMENT

The BRA provides a quantitative estimate of potential risks to human health and the environment from chemical and radiological constituents at the Luckey site. The nature and severity of risks identified influence the development and selection of remedial alternatives. The objectives of the Luckey site risk assessment were to:

- Identify areas that do not pose unacceptable risks to human health or the environment, and thus require no further action.
- Develop a list of preliminary COCs for each EU, which contribute to unacceptable risks to human health or the environment.
- Estimate potential risks to human health and the environment associated with the Luckey site if no remedial action occurs.
- Develop risk-based concentrations (RBCs) and radionuclide action levels for the identified preliminary constituents of concern to provide the basis for preliminary media-specific cleanup goals, in order to focus remedy selection on constituents that are the significant contributors to potential risk.

The methods used in the Luckey site BRAs were originally proposed in the Technical Memorandum and accepted by stakeholders (USACE 1999b). More detailed information can be found in Sections 6 and 7 of the RI Report (USACE 2000a).

The BRA utilized sampling data collected during the RI. These samples were analyzed for inorganic compounds (metals, anions, and radionuclides), SVOCs, VOCs, PCBs, and pesticides, depending on the type and location of the particular sample. Quality Assurance/Quality Control (QA/QC) samples were collected to ensure that the data were valid. More detailed information on data validation, QA/QC samples, blank samples, detection limits, non-detects, etc., can be found in the RI Report.

The risk assessment performed an exposure assessment to identify current and future populations reasonably anticipated to be exposed to constituents of potential concern (COPCs). For purposes of the BRA, the Luckey site was divided into EUs:

- EU 1: On-site undisturbed soil within the current fenced boundaries of the site
- EU 2: On-site disturbed soil within the current fenced boundaries of the site
- EU 3: Off-site land surrounding the facility currently used for residential/agricultural purposes including the former railroad bed (contiguous with site)
- EU 4: Toussaint Creek down-gradient from the Luckey site
- EU 5: France Stone Quarry south of the site
- EU 6: Landfill (Troy Township Dump) south of the site
- EU 7: Groundwater (on-site and off-site).

For EU 2, the term “disturbed soil” refers to the eastern portion of the Luckey site where historic operational and disposal activities occurred (i.e. the lagoons and disposal in excavated trenches). “Undisturbed soil” refers to the remainder of the property (i.e. EU 1).

Environmental media that may transport contaminants to receptors were identified (e.g., air). The route of uptake in the receptor was then identified (e.g., ingestion, inhalation, or absorption). The concentration of each COPC that the receptor was potentially exposed to was estimated, known as the exposure point concentration (EPC). The toxicity of the various COPCs was estimated using the latest data from state, federal, and other appropriate sources such as the National Center for Environmental Assessment and the Agency for Toxic Substances and Disease Registry. The EPC, exposure assessment, and toxicity data all utilize conservative assumptions that build in additional safety factors for the public.

2.4.1 Human Health Risk Assessment

The human health risk assessment (HHRA) evaluated risks to several current and future receptor populations. The Luckey site is zoned light industrial and is expected to remain industrial for the near future. Given the current zoning designation and published expansion plans for the Village of Luckey (Wood County 1998), the most likely future use for the property is industrial or commercial use. However, it is possible future land use could be residential or agricultural for the following reasons: surrounding land use on three sides is agricultural and residential, agricultural and residential are the dominant land uses in Troy Township, there is no other industry in the area, and industrial facilities at the site are aging. Therefore, for current land use, receptors evaluated in the HHRA included industrial workers (on site), resident farmers (off site), and adolescent trespassers (off site). For future land use, receptors included industrial workers (on site), resident farmers (on site and off site), subsistence farmers (on site), and adolescent trespassers (off site). Resident farmers were assumed to reside on site where they may be exposed to site constituents in soil, groundwater, surface water, and sediment. Resident farmers were not assumed to consume a significant portion of food grown on site in their diet and therefore the pathway was not quantified. A subsistence farmer scenario is presented in Appendix 3A of

this FS Report. The subsistence farmer scenario includes all pathways evaluated for the resident farmer, but also includes consumption of food grown or produced on site.

The subsistence farmer was not included in the BRA contained in the RI report (USACE 2000a). Subsequent meetings between site planners and stakeholders resulted in the addition of this receptor to the BRA based on the 10 CFR Part 20 Subpart E and Ohio Administrative Code (OAC) 3701:1-38-22 requirement to evaluate the “critical group” for radionuclides. In Ohio, the critical group for unrestricted land use has been consistently defined as the subsistence farmer. The subsistence farmer is assumed to represent the critical group at the Luckey site for unrestricted land use. Appendix 3A to this FS contains the risk assessment for the subsistence farmer. This receptor was not evaluated previously in the BRA in the RI report for the following reasons: 1) Applicable or Relevant and Appropriate requirements (ARARs) such as OAC 3701:1-38-22 were not chosen until the FS stage, 2) the subsistence farmer scenario is only required by Ohio's definition of the critical group as it pertains to OAC 3710:1-38-22, and 3) Ohio became an NRC agreement state after the BRA in the RI report was completed. Risks for all other receptors were quantified according to EPA procedures as outlined in the Technical Memorandum (USACE 1999b) and Section 6.0 of the RI Report. In general, risk assessment procedures follow EPA's *Risk Assessment Guidance for Superfund* (RAGS). Note, however, that a more recent version of Residual Radiation Computer Code (RESRAD) was used to evaluate radionuclide exposures to the subsistence farmer than was used to evaluate other receptors in the RI Report. Furthermore, some RESRAD modeling parameters were adjusted based on subsequent state agency input. In addition to unrestricted land use, this FS also considers future industrial use of the site. Therefore, RESRAD modeling of radionuclide exposures to the industrial worker receptor were updated to be consistent with those used for the subsistence farmer receptor. This updated risk assessment scenario also is presented in Appendix 3A.

Both non-cancer and cancer risks were evaluated in the HHRA. Risks were quantified for all non-radiological and radiological constituents that were determined to be COPCs. Risks, however, were evaluated separately for non-radiological and radiological constituents because the cancer slope factors used to quantify cancer potential were developed differently for the two classes of compounds. [See additional explanation in the Technical Memorandum for the BRA, Section 3.2.3. (USACE 1999b).] Beryllium, lead, and cadmium are the main contributors to non-cancer risk, with beryllium and lead posing the most risk via ingestion of soil. Manganese in drinking water contributes most non-cancer risk to children from groundwater exposures, but the risk of drinking groundwater is still less than exposure to beryllium and lead in soils. There are no AEC-related chemical constituents in soil that contribute significantly to cancer risk. The highest cancer risk from soil is from exposure to PAHs. There are no chemical carcinogens in groundwater. For radiological COCs, radium-226 contributes the most to risk/dose, via external gamma exposure to soils. Risk from exposure to radionuclides via ingestion of groundwater is three orders of magnitude less than from exposure to soils (Table 2.4).

In the HHRA, any COPC identified as posing a non-cancer hazard index (HI) greater than 1.0 was considered a preliminary COC. Any COPC identified as posing an incremental lifetime cancer risk (ILCR) greater than 10^{-6} also was considered a preliminary COC. An ILCR of 10^{-6} corresponds to the conservative end of the 10^{-4} to 10^{-6} acceptable risk range established by CERCLA. Table 2.5 details the preliminary COCs identified in the HHRA for each EU based on the risk criteria discussed above. No human health COCs were identified in EUs 5 and 6.

Preliminary COCs identified in on-site soils include beryllium, cadmium, lead, several radionuclides, several PAHs such as benzo(a)pyrene, and PCBs in the form of Aroclor 1254. Beryllium and two radionuclides (radium-226 and protactinium-231) were identified in off-site soils immediately north of the site. Manganese, uranium-234, uranium-235, and uranium-238 are the preliminary risk-based COCs identified in groundwater. Benzo(a)pyrene and radium-226 were identified in sediment. Only

beryllium, lead, and radionuclides are constituents related to AEC activities and thus are considered final COCs.

As discussed in Section 1, USACE is not authorized to address COCs that are not related to AEC activities, including PAHs, PCBs, cadmium, and manganese. Therefore, this FS directly addresses only AEC-related, or final, COCs. COCs not related to AEC activities may be addressed indirectly if they are collocated with final AEC-related COCs or if their presence constrains proposed activities to address AEC-related COCs. Lead in EU 2 is the only AEC-related COC under current land use (industrial). Under future land uses, including subsistence farming, beryllium, lead, and radionuclides are AEC-related COCs.

In the HHRA, all radionuclides are evaluated as carcinogens. Only uranium is considered both a carcinogenic and non-carcinogenic hazard. The non-carcinogenic properties of uranium were addressed in the HHRA for non-radiological constituents.

The HHRA for radiological constituents in soil was conducted utilizing RESRAD, Version 5.82. RESRAD uses methods consistent with standard RAGS methods, and the calculations parallel the HHRA for non-radiological constituents. The RESRAD code presents several advantages including: modeling future conditions, accounting for radiological decay, consideration of site-specific variables and source geometry, incorporating all potential exposure pathways into a single calculation, and providing carcinogenic risk and radiological dose estimates for comparison to regulatory limits. Note that RESRAD Version 5.82 was the current version at the time the HHRA was prepared. The subsistence farmer scenario and revised industrial worker scenarios in Appendix 3A of this FS were evaluated using RESRAD Version 6.1, which includes updated slope factors. Therefore, the cleanup goals presented in this FS are consistent with the updated version of RESRAD.

Pathways for non-radiological and radiological constituents generally are the same, however, there are some differences. Radon is a radioactive noble gas that tends to accumulate in enclosed structures and represents a new potential exposure pathway. Radon was evaluated consistent with EPA, NRC, and other relevant agencies. The evaluation included comparing current and potential future concentrations against the EPA guideline of 0.02 Working Level (WL), assumed to be equivalent to 4 pCi/L. Risk from exposure to radon was excluded due to the large number of uncertainties (consistent with federal/state methods). Dermal slope factors are not available for the radiological constituents at the Luckey site. Thus, the dermal contact pathway was not evaluated. External exposure to radionuclides that emit gamma radiation or x-rays must be considered. This external exposure pathway accounts for radionuclides that may produce a risk without direct physical contact.

Consideration of the cumulative effect of all exposure pathways on risk (and subsequent RBCs presented in Section 3) is addressed in several ways for AEC-related, or final, COCs. For radionuclides, the RESRAD program was used, to look at exposures to constituents in soils and groundwater (and other pathways such as inhalation) simultaneously. For lead, the Integrated Exposure Uptake Biokinetic Model (IEUBK) model was used, which as its name states, examines lead exposures from multiple pathways, including soil, water, and food ingestion. For beryllium, the soil cleanup goal is an RBC for a child based on a hazard quotient (HQ) of 1. Non-cancerous effects are the primary concern for exposures to beryllium and lead. The BRA determined that child receptors were susceptible to these effects at lower concentrations than adults. The subsistence farming future land use scenario includes child receptors; therefore, protection of child receptors is necessary to ensure overall protection of human health. As a result, cleanup goals for lead and beryllium were developed to be protective of child receptors under the subsistence farming scenario.

The groundwater cleanup goal is based on the MCL. It is assumed, because the MCL is an ARAR, one would not drink groundwater containing beryllium above the MCL. Therefore, the risk due to consumption of groundwater containing beryllium at the MCL can be quantified. For a child, this equates to a HQ of approximately 0.2. It is appropriate to round hazard indices to one significant figure. Therefore, drinking water containing beryllium at the MCL would not contribute significantly to risks above and beyond risks due to exposure to soils alone.

2.4.2 Ecological Risk Assessment

Similar to a human health risk assessment, an ecological risk assessment (ERA) defines the likelihood of harmful effects to plants and animals as a result of exposure to non-radiological and radiological constituents. Guidance for conducting ERAs can be found in the *Risk Assessment Guidance for Superfund, Volume II, Environmental Evaluation Manual* (EPA 1989a), *Framework for Ecological Risk Assessment* (EPA 1992), and other documents.

There are two basic types of ERAs. A screening ERA uses more generic information and conservative assumptions to determine if there are any indications of potential problems at a site. Since generalized information is used, the screening approach is less data intensive and can be used to quickly eliminate scenarios that do not present a concern. If the screening methodology indicates a potential problem, a baseline ERA can be conducted using more detailed and site-specific data. A screening ERA has been completed in the RI Report. Methods used to perform the screening ERA are contained in the Technical Memorandum (USACE 1999b) and Section 7 of the RI Report (USACE 2000a). The same EUs evaluated in the HHRA were evaluated in the screening ERA.

The screening ERA characterized, in a preliminary manner, the potential risks to plants and animals at the Luckey site. The evaluation was conducted for present and potential future site conditions. Unlike the HHRA, which focuses on potential impacts to individuals, the ERA focuses on animal populations. Individuals are addressed only if they belong to classes protected under the Endangered Species Act.

The only Federally listed endangered species in the area is the Indiana bat (*Myotis sodalis*). The U.S. Fish and Wildlife Service (USFWS) noted that no impact to this species is expected from activities at the Luckey site (USFWS 1997). The Luckey site also is within the range of the bald eagle (*Haliaeetus leucocephalus*), which is a federally listed threatened species. Once again, no impact to this species is expected from activities at the Luckey site.

Screening steps in the ERA include a comparison of indicators of bioaccumulation to screening criteria, and a comparison of maximum EPCs in soil to toxicity screening values. This and other pathway and toxicity information was used to obtain a list of constituents of potential ecological concern (CPECs). The CPECs retained included inorganics, anions, SVOCs, VOCs, PCBs, and radiological constituents.

Unlike the HHRA, deep groundwater is not considered significant for the ERA because contact at depths greater than 5 ft bgs is unlikely. The principal route of exposure is assumed to be soil contact via direct contact and uptake, or indirectly through ingestion of contaminated plants or animals.

Five terrestrial classes (vegetation, soil-dwelling invertebrates, worm-eating and/or insectivorous mammals, mammalian herbivores, and terrestrial top predators) were selected for terrestrial receptors. Ecological receptors chosen for the screening phase included terrestrial plants, earthworms, short-tailed shrew, American robin, cottontail rabbit, white-tailed deer, red-tailed hawk, and red fox. Exposure of these receptors to the CPECs was estimated based on constituent concentrations, pathways, and assumed routes and quantities of uptake.

The ecological assessment endpoints evaluated potential effects using environmental effects quotients (EEQs) for the CPECs. The EEQs form the quantitative basis of the risk characterization (EPA 1989b). EEQs are computed as the ratio of the total average daily dose (ADD) to the toxicity reference value (TRV). An EEQ greater than unity (1.0) indicates there is a potential concern, making the CPEC subject for further investigation.

Risk characterization for radionuclides was performed using a single line of evidence, the calculated chronic external and internal exposure of receptors to radionuclides in soils. An HI was calculated for each location by adding the EEQ values. It is assumed that if HI values are less than one, risk from exposure to radionuclides at that site is within acceptable ranges.

All calculated HI values were below 0.03 for individual EUs and below 0.05 on a site-wide basis. It is therefore assumed that there is no credible risk of harm to ecological receptors from radionuclides in soil at the Luckey site. Although the radium-226 activity will be increased over time by the decay of other radionuclides, the overall increase in exposure of ecological receptors is expected to be less than two-fold. Therefore, the radionuclide risks to ecological receptors will remain negligible. For example, the highest site wide risk, which is to soil invertebrates, may increase from the calculated HI of 0.043 to an HI of less than 0.09. These increases will occur over several thousand years and will be much less for the first 500 years.

The EEQs for animals at the Luckey site in the future are considered to be similar to those in the present. Vegetation is expected to continue colonizing terrestrial areas if natural invasional/successional processes are allowed to proceed. Some organics would be expected to decrease in concentration through natural degradation, although the number and concentration of breakdown products could increase. Overall, future risks are assumed to be similar to present risks at the Luckey site.

Several preliminary ecological COCs (EEQ >1) were identified in various media at the Luckey site. The majority of the preliminary ecological COCs are in the soil at EU 1 and EU 2. For radionuclides, no EEQs or HIs exceeded unity for any receptor. The preliminary ecological COCs (primarily metals) are presented in Table 2.6. Several SVOCs and PCBs in the form of Aroclor 1254 also were identified. Terrestrial areas at the site are not currently managed for ecological purposes, nor are there any plans to manage these areas for ecological purposes in the future. These current and future land uses will allow for minimal habitat for ecological receptors and thus minimal exposure to ecological receptors.

In Section 7.8.1 of the RI report, a weight-of-evidence analysis for on-site soils and vegetation is presented. This analysis compares surface soil concentrations of COCs to field observations of stressed vegetation. In on-site soils, elevated concentrations of beryllium and lead were found to be collocated with areas devoid of vegetation. There was no evidence of chemical/radiological-induced vegetation stress elsewhere on the Luckey site.

The screening ERA indicated that the benthic macroinvertebrate community may be at risk from several preliminary ecological COCs in sediment and surface water in Toussaint Creek (EU 4) and tributaries (EU 3). A few constituents, including beryllium, are present in the sediments, but have no TRVs with which to calculate EEQs. Rapid Bioassessment Protocol results from stations upstream of the Luckey site, and in each of the three segments downstream, indicate that the benthic communities at all sampling stations in Toussaint Creek are impacted, but that conditions improve downstream. Qualitative conclusions from the screening ERA contained uncertainties that prevented a final resolution for the site. These uncertainties included: the lack of toxicity data for beryllium, the overall poor habitat quality in the creek, and the role of other outfalls (e.g., sewage) on stream biota. Discussions with Ohio EPA concerning these uncertainties resulted in the derivation of the additional studies (i.e., a baseline ERA)

using Ohio EPA's protocols for bioassessment of surface waters. Field work for these additional studies was conducted in June and August, 2001 and the results and conclusions are contained in the *Biological and Water Quality Study of Toussaint Creek and Select Tributaries in Support of the Luckey Site Remedial Investigation/Feasibility Study* (USACE 2002a).

The 2001 study results indicate the benthic macroinvertebrate and fish communities in Toussaint Creek are in relatively poor condition. All stations in Toussaint Creek, including the two reference stations, were in nonattainment with Ohio EPA WWH biocriteria. All stations except one downstream location were in partial attainment of Modified Warmwater Habitat (MWH) criteria. The remaining downstream location was in full attainment of MWH. The consistent poor performance across all sampling locations suggests these results may be attributed to regional causes and impacts. The habitat scores at all sites are considered low when compared to WWH expectations, and indicate there are habitat limitations for aquatic life within Toussaint Creek and its tributaries.

The AEC-related constituents, beryllium and lead, are not strong factors in the observed poor conditions of the aquatic communities. The major factors affecting the biological communities in Toussaint Creek appear to be regional or landscape-level factors including: poor instream habitat, inadequate riparian zones, relatively small drainage areas, non-point source runoff resulting from intensive agriculture and historic deforestation, and periodic low flow/high flow conditions exaggerated by the channelization of the stream. In addition, both treated and untreated sewage outfalls from the Village of Luckey, in combination with low flow conditions, likely cause low dissolved oxygen conditions at downstream sites potentially for several miles. Measured dissolved oxygen concentrations were, at times, threatening to aquatic life. Based on these conclusions, no AEC-related constituents in Toussaint Creek and select tributaries are retained as ecological COCs, therefore no further action is required for Toussaint Creek and select tributaries.

Table 2.1. Timeline of Pertinent Beryllium-related Operational Activities at the Luckey Site

Year	Event/Activity
1949	Brush Beryllium Company (BBC) leases site and contracts with the Atomic Energy Commission (AEC) to construct, operate, and maintain beryllium production facility at the Luckey site.
1950-?	Contaminated scrap beryllium is received for reprocessing. Historical records indicate beryllium scrap from other AEC operations was being sent to the Luckey site for reprocessing. Indications are that some of this scrap was contaminated with radionuclides (Smith 1950).
1951-1952	Korean War begins in 1951. Plans are made and subsequently dropped to restart the magnesium reduction plant. In Late 1951, AEC shipped approximately 1,000 tons of scrap steel containing various radionuclides from the Lake Ontario Storage Area (LOSA) to the Luckey site (③ on Figure 2.3). The steel was to be utilized in the magnesium reduction process. A limited quantity was usable by BBC. Some scrap may have been sold to local scrap dealers and some may have been disposed in trenches 5, 6, or 7.
1950-1958	The sludge from Lagoons A, B, and C was dredged every summer and placed into disposal trenches in the northeast corner of the facility (trenches 1 through 4).
1955?/1959?	Possible excavation of trench 5 to receive scrap metal and/or steel. This trench also was reportedly constructed in 1959 as part of site closure activities.
1958	Beryllium production operations are discontinued at Luckey.
1959	Site closure activities are performed. The buildings were purported to have been decontaminated. Decontamination plans included dismantling/disposing process equipment and steam cleaning building interiors. Process piping and ventilation ducts in the Annex were dismantled and reported to have been sent to Oak Ridge, Tennessee or disposed on site. Historical records indicate scrap metal, building debris, and graphite crucibles with soluble beryllium fluoride, and possibly sludge from Lagoons A, B, and C were placed into excavated trenches (trenches 5, 6, and 7). Sludge dredged from Lagoons A, B, and C also may have been placed in the “disposal area” located in the northeast corner.
1957-1960	Sintering and powder metallurgy activities involving beryllium are conducted at the facility.
1961	Circa 1961, AEC-related beryllium sintering operations ceased. Available historical records are not clear on exact termination of AEC-related activities at the Luckey site, however the facility was sold to Aluminum and Magnesium, Inc in 1961.
1988	Lagoons A and B are capped in 1988 to eliminate wind dispersal of dust.

Table 2.2. Summary of Soil Analytical Results

Parameter	Detection Frequency	Minimum Value	Minimum Location	Maximum Value	Maximum Location	Background	Background Exceed	Soil PRG* (mg/kg)	Units
Disposal Trenches and Pits - Northeast Corner (Trenches 1 - 4)									
Metals									
Arsenic	69/73	1.5	IA01-SB0007	33.5	IA01-SB0004	24.1	2/69	4	mg/kg
Barium	68/68	12.4	IA01-SB0001	301	IA01-SB0007	209	1/68	5375	mg/kg
Beryllium	192/192	0.17 B	IA01-SB0002	8760	IA01-SB0035	1.13	123/192	154	mg/kg
Lead	68/68	4.9 *	IA01-SB0011	28900 J	10FD01	23.2	26/68	400	mg/kg
Radiological Parameters									
Radium-226	76/76	0.891 J	IA01-SB0022	193 J	10FI01	2.97	28/76	--	pCi/g
Radium-228	73/76	0.0945	10FI01	1.42	IA01-SB0007	1.48	0/73	--	pCi/g
Thorium-228	76/76	0.0945	10FI01	2.11	IA01-SB0003	1.6	4/76	--	pCi/g
Thorium-230	76/76	1.06	IA01-SB0011	60.3	09EJ01	3.2	28/76	--	pCi/g
Thorium-232	76/76	0.104	10FI01	1.46	IA01-SB0011	1.48	0/76	--	pCi/g
Thorium-234	41/61	1.08 J	IA01-SB0021	43.3	IA01-SB0018	3.07	14/41	--	pCi/g
Uranium-233/234	61/61	0.554 J	IA01-SB0022	43.2	IA01-SB0018	2.01	15/61	--	pCi/g
Uranium-234	15/15	2.4	11EV01	31.1	09EJ01	2.61	14/15	11.3	pCi/g
Uranium-235	42/76	0.0492	IA01-SB0014	2.29	IA01-SB0018	0.25	21/42	--	pCi/g
Uranium-238	76/76	0.708 J	IA01-SB0009	41.5	IA01-SB0018	2.63	27/76	--	pCi/g
Disposal Trenches and Pits - Scrap Metal Disposal Trench (Trench 7)									
Metals									
Arsenic	33/33	2.6	IA03-SB0002	39.4	10DD00	24.1	1/33	4	mg/kg
Barium	30/30	19.9 N	IA03-SB0007	218 J	10DD00	209	1/30	5375	mg/kg
Beryllium	84/84	0.19 B	IA03-SB0007	1300	IA03-TR0002	1.13	36/84	154	mg/kg
Lead	33/33	5.2 E	IA03-SB0007	780	10DD00	23.2	5/33	400	mg/kg
Radiological Parameters									
Radium-226	33/33	0.878 J	IA03-SB0010	2.12	IA03-SB0005	2.97	0/33	--	pCi/g
Radium-228	31/33	0.489 J	IA03-SB0006	1.22	IA03-SB0010	1.48	0/31	--	pCi/g
Thorium-228	33/33	0.255 J	IA03-SB0002	2.1	IA03-SB0009	1.6	2/33	--	pCi/g
Thorium-230	33/33	0.827	10CM01	2.88	10DD00	3.2	0/33	--	pCi/g
Thorium-232	33/33	0.183 J	IA03-SB0002	1.75	IA03-SB0009	1.48	1/33	--	pCi/g
Thorium-234	20/29	0.676 J	IA03-SB0010	3.33 J	IA03-SB0007	3.07	1/20	--	pCi/g
Uranium-233/234	29/29	0.654 J	IA03-SB0017	2.8	IA03-SB0003	2.01	1/29	--	pCi/g
Uranium-234	4/4	0.51	10DD00	1.03	10CX01	2.61	0/4	11.3	pCi/g
Uranium-235	9/33	0.0594	10CS01	0.13 J	IA03-SB0010	0.25	0/9	--	pCi/g
Uranium-238	33/33	0.533	10DD00	2.7	IA03-SB0003	2.63	1/33	--	pCi/g

*USEPA Region 9 PRG (residential)

Data qualifiers (J, N, B, and E) are defined in Appendix 2A, Table 2A.1.

Table 2.2. Summary of Soil Analytical Results

Parameter	Detection Frequency	Minimum Value	Minimum Location	Maximum Value	Maximum Location	Background	Background Exceed	Soil PRG* (mg/kg)	Units
Disposal Trenches and Pits - NE of Filter Beds (Trench 5)									
<i>Metals</i>									
Arsenic	34/34	4	IA05-SB0007	20.8 *	IA05-SB0020	24.1	0/34	4	mg/kg
Barium	29/29	23.1	IA05-SB0007	789	IA05-SB0008	209	1/29	5375	mg/kg
Beryllium	52/52	0.3	IA05-SB0022	8620 N	IA05-SB0007	1.13	40/52	154	mg/kg
Lead	34/34	9.2	IA05-SB0007	627	IA05-SB0007	23.2	13/34	400	mg/kg
<i>Radiological Parameters</i>									
Radium-226	29/29	1.06	IA05-SB0007	9.71	IA05-SB0007	2.97	3/29	--	pCi/g
Radium-228	29/29	0.293 J	IA05-SB0007	1.33	IA05-SB0020	1.48	0/29	--	pCi/g
Thorium-228	29/29	0.51 J	IA05-SB0007	1.47	IA05-SB0020	1.6	0/29	--	pCi/g
Thorium-230	29/29	0.928 J	IA05-SB0021	15.7	IA05-SB0007	3.2	2/29	--	pCi/g
Thorium-232	29/29	0.237 J	IA05-SB0007	1.27	IA05-SB0018	1.48	0/29	--	pCi/g
Thorium-234	15/27	1.08 J	IA05-SB0021	6.61	IA05-SB0007	3.07	2/15	--	pCi/g
Uranium-233/234	27/27	0.54 J	IA05-SB0021	7.98	IA05-SB0007	2.01	3/27	--	pCi/g
Uranium-234	2/2	0.742	08FS01	0.968	08FS02	2.61	0/2	11.3	pCi/g
Uranium-235	11/29	0.0672	IA05-SB0021	0.545 J	IA05-SB0007	0.25	1/11	--	pCi/g
Uranium-238	29/29	0.816 J	IA05-SB0020	8.11	IA05-SB0007	2.63	2/29	--	pCi/g
Uranium-238	10/10	0.0977	IA07-SB0009	1.41	IA07-SB0009	2.63	0/10	--	pCi/g

*USEPA Region 9 PRG (residential)

Data qualifiers (J, N, B, and E) are defined in Appendix 2A, Table 2A.1.

Table 2.2. Summary of Soil Analytical Results

Parameter	Detection Frequency	Minimum Value	Minimum Location	Maximum Value	Maximum Location	Background	Background Exceed	Soil PRG* (mg/kg)	Units
Lagoon A									
<i>Metals</i>									
Arsenic	12/13	2.1	IA02-SB0010	11.4	IA02-SB0005	24.1	0/12	4	mg/kg
Barium	13/13	35.2 B	04AX00	292	IA02-SB0005	209	1/13	5375	mg/kg
Beryllium	27/27	0.43	IA02-SB0020	7880	04AX00	1.13	13/27	154	mg/kg
Lead	13/13	5.9	IA02-SB0010	135 B	04AX00	23.2	1/13	400	mg/kg
<i>Radiological Parameters</i>									
Radium-226	13/13	1.05 J	04AX00	22.4 J	04AX00	2.97	1/13	--	pCi/g
Radium-228	12/13	0.41	04AX00	1.2	IA02-SB0005	1.48	0/12	--	pCi/g
Thorium-228	13/13	0.41	04AX00	1.67	IA02-SB0011	1.6	1/13	--	pCi/g
Thorium-230	13/13	0.876	04AX00	25.6 J	04AX00	3.2	1/13	--	pCi/g
Thorium-232	13/13	0.268	04AX00	1.23 J	04AX00	1.48	0/13	--	pCi/g
Thorium-234	3/11	1.47 J	IA02-SB0012	1.77 J	IA02-SB0011	3.07	0/3	--	pCi/g
Uranium-233/234	11/11	0.828 J	IA02-SB0005	1.68	IA02-SB0011	2.01	0/11	--	pCi/g
Uranium-234	2/2	4.86	04AX00	52.3	04AX00	2.61	2/2	11.3	pCi/g
Uranium-235	7/13	0.0524	IA02-SB0012	0.559 J	04AX00	0.25	2/7	--	pCi/g
Uranium-238	13/13	0.949 J	IA02-SB0012	51.1	04AX00	2.63	2/13	--	pCi/g
Lagoon B									
<i>Metals</i>									
Arsenic	15/15	3.3	IA02-SB0014	12.7 B	05BE00	24.1	0/15	4	mg/kg
Barium	15/15	17.8	05BE00	171	05BE00	209	0/15	5375	mg/kg
Beryllium	38/38	0.51 J	IA02-SB0025	2920	05BE00	1.13	22/38	154	mg/kg
Lead	15/15	6.8	IA02-SB0014	122	IA02-SB0013	23.2	3/15	400	mg/kg
<i>Radiological Parameters</i>									
Radium-226	15/15	1.08	IA02-SB0014	37.4 J	05BE00	2.97	3/15	--	pCi/g
Radium-228	15/15	0.171	05BE00	1.22	IA02-SB0014	1.48	0/15	--	pCi/g
Thorium-228	15/15	0.171	05BE00	1.51	IA02-SB0014	1.6	0/15	--	pCi/g
Thorium-230	15/15	1.16	IA02-SB0013	24.6	05BE00	3.2	1/15	--	pCi/g
Thorium-232	15/15	0.253	05BE00	1.3	IA02-SB0004	1.48	0/15	--	pCi/g
Thorium-234	10/13	1.2 J	IA02-SB0004	4.06 J	IA02-SB0004	3.07	2/10	--	pCi/g
Uranium-233/234	13/13	0.843 J	IA02-SB0013	3.29	IA02-SB0004	2.01	1/13	--	pCi/g
Uranium-234	2/2	6.8	05BE00	13.1	05BE00	2.61	2/2	11.3	pCi/g
Uranium-235	8/15	0.0496	IA02-SB0014	0.527 J	05BE00	0.25	2/8	--	pCi/g
Uranium-238	15/15	0.808 J	IA02-SB0014	14.6	05BE00	2.63	3/15	--	pCi/g

*USEPA Region 9 PRG (residential)

Data qualifiers (J, N, B, and E) are defined in Appendix 2A, Table 2A.1.

Table 2.2. Summary of Soil Analytical Results

Parameter	Detection Frequency	Minimum Value	Minimum Location	Maximum Value	Maximum Location	Background	Background Exceed	Soil PRG* (mg/kg)	Units
Lagoon C									
<i>Metals</i>									
Arsenic	26/26	2.3 B	08AW00	98.7	08AW00	24.1	2/26	4	mg/kg
Barium	21/21	24	08AW00	2250	08AW00	209	1/21	5375	mg/kg
Beryllium	46/46	0.31	IA02-SB0016	3840	IA02-SB0001	1.13	23/46	154	mg/kg
Lead	21/21	9	IA02-SB0002	88.5	IA02-SB0007	23.2	8/21	400	mg/kg
<i>Radiological Parameters</i>									
Radium-226	34/34	1.31	IA02-SB0009	32.1 J	08AW00	2.97	14/34	--	pCi/g
Radium-228	33/34	0.227	08AW00	1.35	IA02-SB0007	1.48	0/33	--	pCi/g
Thorium-228	34/34	0.227	08AW00	1.4	IA02-SB0006	1.6	0/34	--	pCi/g
Thorium-230	34/34	0.872	10AX00	15.2	IA02-SB0001	3.2	6/34	--	pCi/g
Thorium-232	34/34	0.162 J	IA02-SB0001	1.04	IA02-SB0009	1.48	0/34	--	pCi/g
Thorium-234	10/17	1.03 J	IA02-SB0006	27.6	IA02-SB0001	3.07	3/10	--	pCi/g
Uranium-233/234	17/17	0.962 J	IA02-SB0007	24.2	IA02-SB0001	2.01	5/17	--	pCi/g
Uranium-234	17/17	0.738	10AX00	9.43	08AW00	2.61	4/17	11.3	pCi/g
Uranium-235	24/34	0.0426	10BB01	1.89	IA02-SB0001	0.25	3/24	--	pCi/g
Uranium-238	34/34	0.658	10AX00	27.8	IA02-SB0001	2.63	8/34	--	pCi/g
Lagoon D									
<i>Metals</i>									
Arsenic	6/6	7.3	IA03-SB0001	12.7	IA03-SB0008	24.1	0/6	4	mg/kg
Barium	6/6	89	IA03-SB0008	149	IA03-SB0008	209	0/6	5375	mg/kg
Beryllium	18/18	0.36	IA03-SB0016	26.6	IA03-TR0001	1.13	6/18	154	mg/kg
Lead	6/6	10.2	IA03-SB0001	51.9	IA03-SB0008	23.2	2/6	400	mg/kg
<i>Indicator Parameters</i>									
Fluoride	4/4	1.6	IA03-SB0008	20.1	IA03-SB0008	6.94	1/4	3666	mg/kg
Nitrogen, Ammonia	4/4	0.92 J	IA03-SB0008	21.7	IA03-SB0008	--	--	--	mg/kg
<i>Radiological Parameters</i>									
Radium-226	6/6	1.31	IA03-SB0008	1.76	IA03-SB0001	2.97	0/6	--	pCi/g
Radium-228	6/6	0.85 J	IA03-SB0001	1.45	IA03-SB0008	1.48	0/6	--	pCi/g
Thorium-228	6/6	0.945 J	IA03-SB0008	1.44	IA03-SB0008	1.6	0/6	--	pCi/g
Thorium-230	6/6	1.59	IA03-SB0008	2.1	IA03-SB0008	3.2	0/6	--	pCi/g
Thorium-232	6/6	0.617 J	IA03-SB0001	1.13	IA03-SB0008	1.48	0/6	--	pCi/g
Thorium-234	5/6	0.542 J	IA03-SB0008	2.2 J	IA03-SB0001	3.07	0/5	--	pCi/g
Uranium-233/234	6/6	0.905 J	IA03-SB0008	1.35	IA03-SB0008	2.01	0/6	--	pCi/g
Uranium-235	2/6	0.0728	IA03-SB0001	0.214 J	IA03-SB0008	0.25	0/2	--	pCi/g
Uranium-238	6/6	0.833 J	IA03-SB0008	1.6	IA03-SB0008	2.63	0/6	--	pCi/g

*USEPA Region 9 PRG (residential)

Data qualifiers (J, N, B, and E) are defined in Appendix 2A, Table 2A.1.

Table 2.2. Summary of Soil Analytical Results

Parameter	Detection Frequency	Minimum Value	Minimum Location	Maximum Value	Maximum Location	Background	Background Exceed	Soil PRG* (mg/kg)	Units
Bare Spot									
<i>Metals</i>									
Arsenic	10/10	7.9	IA07-SB0005	21.8	IA07-SB0004	24.1	0/10	4	mg/kg
Barium	10/10	55.1 N	IA07-SB0005	2440 J	06FD00	209	2/10	5375	mg/kg
Beryllium	20/20	0.66	IA07-SB0005	2510	06FD00	1.13	16/20	154	mg/kg
Lead	10/10	10.1 J	IA07-SB0003	9380	06FD00	23.2	4/10	400	mg/kg
<i>Radiological Parameters</i>									
Radium-226	10/10	1.13	IA07-SB0004	6.96 J	06FD00	2.97	1/10	--	pCi/g
Radium-228	10/10	0.636	06FD00	1.17	IA07-SB0003	1.48	0/10	--	pCi/g
Thorium-228	10/10	0.636	06FD00	1.63	IA07-SB0005	1.6	1/10	--	pCi/g
Thorium-230	10/10	1.82 J	IA07-SB0004	30.6	06FD00	3.2	1/10	--	pCi/g
Thorium-232	10/10	0.53	06FD00	1.44	IA07-SB0003	1.48	0/10	--	pCi/g
Thorium-234	5/9	1.49 J	IA07-SB0003	2.44 J	IA07-SB0005	3.07	0/5	--	pCi/g
Uranium-233/234	9/9	1.84	IA07-SB0003	3.14	IA07-SB0005	2.01	4/9	--	pCi/g
Uranium-234	1/1	9.27	06FD00	9.27	06FD00	2.61	1/1	11.3	pCi/g
Uranium-235	7/10	0.167 J	IA07-SB0004	0.429	06FD00	0.25	3/7	--	pCi/g
Uranium-238	10/10	1.86	IA07-SB0003	8.5	06FD00	2.63	1/10	--	pCi/g
Stressed Vegetation									
<i>Metals</i>									
Arsenic	9/9	4.3	IA07-SB0008	15.2	IA07-SB0007	24.1	0/9	4	mg/kg
Barium	9/9	62	IA07-SB0008	115	IA07-SB0008	209	0/9	5375	mg/kg
Beryllium	15/15	0.61	IA07-SB0007	70.1	IA07-SB0007	1.13	9/15	154	mg/kg
Lead	9/9	7.4 J	IA07-SB0008	19.7	IA07-SB0006	23.2	0/9	400	mg/kg
<i>Radiological Parameters</i>									
Radium-226	12/12	1.07	IA07-SB0006	21 J	05FR01	2.97	3/12	--	pCi/g
Radium-228	12/12	0.5	05FR01	1.18	IA07-SB0008	1.48	0/12	--	pCi/g
Thorium-228	12/12	0.5	05FR01	1.56 J	IA07-SB0008	1.6	0/12	--	pCi/g
Thorium-230	12/12	1.51 J	IA07-SB0006	19.2	05FR01	3.2	3/12	--	pCi/g
Thorium-232	12/12	0.528	05FL02	1.27 J	IA07-SB0007	1.48	0/12	--	pCi/g
Thorium-234	4/9	0.925 J	IA07-SB0007	1.82 J	IA07-SB0007	3.07	0/4	--	pCi/g
Uranium-233/234	9/9	0.707 J	IA07-SB0008	1.48 J	IA07-SB0007	2.01	0/9	--	pCi/g
Uranium-234	3/3	14.2	05FS00	25.8	05FL02	2.61	3/3	11.3	pCi/g
Uranium-235	3/12	0.633	05FS00	1.02	05FL02	0.25	3/3	--	pCi/g
Uranium-238	12/12	0.738 J	IA07-SB0006	26.6	05FR01	2.63	3/12	--	pCi/g

*USEPA Region 9 PRG (residential)

Data qualifiers (J, N, B, and E) are defined in Appendix 2A, Table 2A.1.

Table 2.2. Summary of Soil Analytical Results

Parameter	Detection Frequency	Minimum Value	Minimum Location	Maximum Value	Maximum Location	Background	Background Exceed	Soil PRG* (mg/kg)	Units
Debris Piles and Filter Bed Area									
<i>Metals</i>									
Arsenic	39/39	2.5	IA05-SB0011	18.1	IA05-SB0010	24.1	0/39	4	mg/kg
Barium	34/34	48.6	IA05-SB0002	322	IA05-SB0005	209	5/34	5375	mg/kg
Beryllium	65/65	0.07 B	IA05-SB0001	13300	IA05-SB0009	1.13	52/65	154	mg/kg
Lead	41/41	6.9 B	08EX00	2670 N*	IA05-SB0017	23.2	18/41	400	mg/kg
<i>Radiological Parameters</i>									
Radium-226	37/37	0.504 J	IA05-SB0002	41.4	IA05-SB0009	2.97	5/37	--	pCi/g
Radium-228	37/37	0.314 J	IA05-SB0002	1.6	IA05-SB0009	1.48	1/37	--	pCi/g
Thorium-228	37/37	0.483	08EI01	1.56 J	IA05-SB0001	1.6	0/37	--	pCi/g
Thorium-230	37/37	0.727 J	IA05-SB0002	88.5	IA05-SB0009	3.2	4/37	--	pCi/g
Thorium-232	36/37	0.405 J	IA05-SB0011	1.19	IA05-SB0012	1.48	0/36	--	pCi/g
Thorium-234	14/31	1.19 J	IA05-SB0006	25.3	IA05-SB0009	3.07	3/14	--	pCi/g
Uranium-233/234	31/31	0.69 J	IA05-SB0004	30.3 J	IA05-SB0009	2.01	4/31	--	pCi/g
Uranium-234	6/6	0.475	08FE00	10.2	08ED01	2.61	2/6	11.3	pCi/g
Uranium-235	18/37	0.0425	08FE00	2.88 J	IA05-SB0009	0.25	3/18	--	pCi/g
Uranium-238	37/37	0.396	08EX00	28.7 J	IA05-SB0009	2.63	4/37	--	pCi/g
Existing Buildings and Associated Areas									
<i>Metals</i>									
Arsenic	28/30	1.3	IA07-SB0001	13.8	IA04-SB0028	24.1	0/28	4	mg/kg
Barium	29/29	1.6	IA04-SB0026	563	IA04-SB0028	209	2/29	5375	mg/kg
Beryllium	75/75	0.25	IA07-SB0002	57.1	IA04-SB0018	1.13	35/75	154	mg/kg
Lead	30/30	6.5	IA04-SB0026	106	IA04-SB0021	23.2	11/30	400	mg/kg
<i>Radiological Parameters</i>									
Radium-226	29/29	0.0887	IA04-SB0026	2.31	IA04-SB0018	2.97	0/29	--	pCi/g
Radium-228	26/29	0.338 J	IA07-SB0001	1.25	IA04-SB0017	1.48	0/29	--	pCi/g
Thorium-228	26/29	0.316 J	IA07-SB0001	2.72	IA08-SB0003	1.6	0/29	--	pCi/g
Thorium-230	28/29	0.588 J	05EI00	2.75	IA04-SB0018	3.2	0/28	--	pCi/g
Thorium-232	26/29	0.325 J	IA07-SB0001	1.5	IA08-SB0003	1.48	1/26	--	pCi/g
Thorium-234	16/28	0.393 J	IA04-SB0026	3.22 J	IA04-SB0019	3.07	2/16	--	pCi/g
Uranium-233/234	27/28	0.137 J	IA04-SB0026	1.75	IA04-SB0018	2.01	0/27	--	pCi/g
Uranium-234	1/1	0.35	05EI00	0.35	05EI00	2.61	0/1	11.3	pCi/g
Uranium-235	10/29	0.0611	IA08-TR0001	0.332 J	IA07-SB0001	0.25	1/10	--	pCi/g
Uranium-238	29/29	0.181 J	IA04-SB0026	2	IA04-SB0018	2.63	0/29	--	pCi/g

*USEPA Region 9 PRG (residential)

Data qualifiers (J, N, B, and E) are defined in Appendix 2A, Table 2A.1.

Table 2.2. Summary of Soil Analytical Results

Parameter	Detection Frequency	Minimum Value	Minimum Location	Maximum Value	Maximum Location	Background	Background Exceed	Soil PRG* (mg/kg)	Units
Northern Farm Field									
<i>Metals</i>									
Arsenic	17/17	5	IA10-SB0031	14.8	IA10-SB0023	24.1	0/17	4	mg/kg
Barium	17/17	79.8	IA10-SB0033	129	IA10-SB0023	209	0/17	5375	mg/kg
Beryllium	49/49	0.63 B	A09-OMW-32(B	744	IA10-SB0043	1.13	37/49	154	mg/kg
Lead	17/17	12.9 *	IA10-SB0031	174	IA10-SB0043	23.2	5/17	400	mg/kg
<i>Radiological Parameters</i>									
Radium-226	17/17	1.45	IA10-SB0035	6.56	IA10-SB0023	2.97	3/17	--	pCi/g
Radium-228	17/17	0.919 J	IA10-SB0044	1.4	IA10-SB0023	1.48	0/17	--	pCi/g
Thorium-228	17/17	0.878 J	IA10-SB0034	1.5	IA10-SB0040	1.6	0/17	--	pCi/g
Thorium-230	17/17	1.39	IA10-SB0035	9	IA10-SB0023	3.2	4/17	--	pCi/g
Thorium-232	17/17	0.6 J	IA10-SB0036	1.32	IA10-SB0038	1.48	0/17	--	pCi/g
Thorium-234	13/17	1.26 J	IA10-SB0031	6.18	IA10-SB0043	3.07	3/13	--	pCi/g
Uranium-233/234	17/17	0.937 J	IA10-SB0039	5.83	IA10-SB0023	2.01	4/17	--	pCi/g
Uranium-235	8/17	0.0516	IA10-SB0039	0.374 J	IA10-SB0023	0.25	1/8	--	pCi/g
Uranium-238	17/17	0.918 J	IA10-SB0033	5.75	IA10-SB0023	2.63	3/17	--	pCi/g
Abandoned Railroad Bed (Eastern Boundary)									
<i>Metals</i>									
Arsenic	10/10	2.4 N	IA10-SB0051	15.6 N	IA10-SB0045	24.1	0/10	4	mg/kg
Barium	10/10	25.4	IA10-SB0053	479	IA10-SB0045	209	1/10	5375	mg/kg
Beryllium	18/18	2.2 N	IA10-SB0046	2560 N	IA10-SB0051	1.13	18/18	154	mg/kg
Lead	10/10	8.9 N	IA10-SB0045	338 N	IA10-SB0050	23.2	7/10	400	mg/kg
<i>Radiological Parameters</i>									
Radium-226	18/18	1.09	IA10-SB0046	24.7	IA10-SB0051	2.97	4/18	--	pCi/g
Radium-228	17/18	0.527 J	IA10-SB0049	1.33	IA10-SB0045	1.48	0/17	--	pCi/g
Thorium-228	18/18	0.248 J	IA10-SB0053	1.27	IA10-SB0094	1.6	0/18	--	pCi/g
Thorium-230	18/18	0.951 J	IA10-SB0097	14.8	IA10-SB0051	3.2	3/18	--	pCi/g
Thorium-232	17/18	0.508 J	IA10-SB0097	1.15	IA10-SB0045	1.48	0/17	--	pCi/g
Thorium-234	13/18	1.28 J	IA10-SB0090	16.3	IA10-SB0051	3.07	5/13	--	pCi/g
Uranium-233/234	18/18	0.761 J	IA10-SB0095	17.8	IA10-SB0051	2.01	5/18	--	pCi/g
Uranium-235	10/18	0.0813	IA10-SB0046	1.42	IA10-SB0051	0.25	3/10	--	pCi/g
Uranium-238	18/18	0.908 J	IA10-SB0046	16.6	IA10-SB0051	2.63	5/18	--	pCi/g

*USEPA Region 9 PRG (residential)

Data qualifiers (J, N, B, and E) are defined in Appendix 2A, Table 2A.1.

Table 2.3. Summary of Groundwater Analytical Results

Parameter	Monitoring Well	Detection Frequency	Minimum Value	Maximum Value	Average Value	Background	Drinking Water Standard*	Exceed Standard	Units
Beryllium	MW-01(I)	10/10	11.8	39.5	31.7	0.79	4	10/10	ug/l
Beryllium (Filtered)	MW-01(I)	7/7	11	33.5	24.53	--	4	7/7	ug/l
Lead	MW-01(I)	3/8	2.2	7.8	2.98	7.2	15	0/3	ug/l
Lead (Filtered)	MW-01(I)	4/7	1.78	9.08	3.11	1.8	15	0/4	ug/l
Uranium, total	MW-01(I)	10/10	2.36	5.65	3.21	--	30	0/10	ug/l
Beryllium	MW-02(S)	10/10	10.8	76.2	31.35	0.79	4	10/10	ug/l
Beryllium (Filtered)	MW-02(S)	7/7	9.12	70.8	31.95	--	4	7/7	ug/l
Lead	MW-02(S)	7/8	2.9	10.4	4.45	7.2	15	0/7	ug/l
Lead (Filtered)	MW-02(S)	4/7	3.3	9.3	4.01	1.8	15	0/4	ug/l
Uranium, total	MW-02(S)	10/10	4.2	8.52	5.76	--	30	0/10	ug/l
Beryllium	MW-13(S)	4/5	0.67	3.3	1.14	0.79	4	0/4	ug/l
Beryllium (Filtered)	MW-13(S)	1/3	0.28	0.28	0.23	--	4	0/1	ug/l
Lead	MW-13(S)	4/5	1.9	19.3	7.29	7.2	15	1/4	ug/l
Lead (Filtered)	MW-13(S)	1/3	2	2	2.14	1.8	15	0/1	ug/l
Uranium, total	MW-13(S)	6/6	4.68	25.93	20.69	--	30	0/6	ug/l
Beryllium	MW-19(I)	7/8	2.4	6.93	4.18	0.79	4	3/7	ug/l
Beryllium (Filtered)	MW-19(I)	6/7	2.5	3.9	3.12	--	4	0/6	ug/l
Lead	MW-19(I)	3/8	1.4	9.47	3.01	7.2	15	0/3	ug/l
Lead (Filtered)	MW-19(I)	1/7	8.65	8.65	2.89	1.8	15	0/1	ug/l
Uranium, total	MW-19(I)	7/10	0.43	0.73	0.55	--	30	0/7	ug/l
Beryllium	MW-21(I)	0/7	ND	ND	ND	0.79	4	--	ug/l
Beryllium (Filtered)	MW-21(I)	1/7	0.21	0.21	0.76	--	4	0/1	ug/l
Lead	MW-21(I)	7/7	25.7	48.5	37.73	7.2	15	7/7	ug/l
Lead (Filtered)	MW-21(I)	7/7	16.6	46.2	33.5	1.8	15	7/7	ug/l
Uranium, total	MW-21(I)	10/10	14.9	34.75	25.38	--	30	2/10	ug/l
Beryllium	MW-24(S)	3/8	0.26	0.47	0.73	0.79	4	0/3	ug/l
Beryllium (Filtered)	MW-24(S)	2/7	0.17	0.18	0.77	--	4	0/2	ug/l
Lead	MW-24(S)	8/8	9.8	15.4	12.13	7.2	15	2/8	ug/l
Lead (Filtered)	MW-24(S)	7/7	5.56	15.9	10.33	1.8	15	1/7	ug/l
Uranium, total	MW-24(S)	10/10	197	389.86	287.09	--	30	10/10	ug/l
Beryllium	MW-26(S)	3/3	57.7	170	115.57	0.79	4	3/3	ug/l
Beryllium (Filtered)	MW-26(S)	3/3	38.6	137	92.87	--	4	3/3	ug/l
Lead	MW-26(S)	3/3	10	16.7	14.2	7.2	15	2/3	ug/l
Lead (Filtered)	MW-26(S)	1/3	2.95	2.95	2.64	1.8	15	0/1	ug/l
Uranium, total	MW-26(S)	6/6	9.46	14.05	11.97	--	30	0/6	ug/l
Beryllium	PW(E)	0/14	ND	ND	ND	0.79	4	--	ug/l
Beryllium (Filtered)	PW(E)	0/5	ND	ND	ND	--	4	--	ug/l
Lead	PW(E)	1/14	1.91	1.91	1.89	7.2	15	0/1	ug/l
Lead (Filtered)	PW(E)	1/5	2.53	2.53	2.44	1.8	15	0/1	ug/l
Uranium, total	PW(E)	8/18	0.34	0.82	0.44	--	30	0/8	ug/l
Beryllium	PW(W)	10/10	9.3	13.2	11.13	0.79	4	10/10	ug/l
Beryllium (Filtered)	PW(W)	1/1	9.82	9.82	9.82	--	4	1/1	ug/l
Lead	PW(W)	5/5	3.4	12.2	7.25	7.2	15	0/5	ug/l
Lead (Filtered)	PW(W)	1/1	3.72	3.72	3.72	1.8	15	0/1	ug/l
Uranium, total	PW(W)	4/4	7.98	10.49	9.2	--	30	0/4	ug/l

* MCL for beryllium and total uranium; action level for lead

Total uranium represented by laboratory total uranium results and the conversion of Uranium-238 activities to a total uranium weight

Table 2.4. Summary of Baseline Human Health Risks for Reasonable Maximum Exposure Scenarios

Exposure Unit	Receptor	Risk Summary	Major Pathways
Exposure Unit 1 (On-site undisturbed soils)	Current/Future Industrial Worker	HI = 0.34 ILCR = 6.6×10^{-5} (non-rad) ILCR = 7.6×10^{-5} (rad)	Dermal contact with soil and External gamma from soil
	Future Resident Farmer Adult (0 – 2 ft soil)	HI = 1.9 ILCR = 8.5×10^{-4} (non-rad) ILCR = 1.1×10^{-3} (rad)	Dermal contact with soil, External gamma from soil, and Ingestion of groundwater
	Future Resident Farmer Adult (0 – 10 ft soil)	HI = 1.9 ILCR = 3.4×10^{-4} (non-rad) ILCR = 4.6×10^{-4} (rad)	Dermal contact with soil, External gamma from soil, and Ingestion of groundwater
	Future Resident Farmer Child (0 – 2 ft soil)	HI = 5.9 ILCR = 5.2×10^{-4} (non-rad) ILCR = 2.2×10^{-4} (rad)	Incidental soil ingestion, External gamma from soil, and Ingestion of groundwater
	Future Resident Farmer Child (0 – 10 ft soil)	HI = 5.7 ILCR = 2.1×10^{-4} (non-rad) ILCR = 9.6×10^{-5} (rad)	Incidental soil ingestion, External gamma from soil, and Ingestion of groundwater
Exposure Unit 2 (On-site disturbed soils)	Current/Future Industrial Worker	HI = 0.8 ILCR = 1.6×10^{-6} (non-rad) ILCR = 5.2×10^{-5} (rad)	Dermal contact with soil and External gamma from soil
	Future Resident Farmer Adult (0 – 2 ft soil)	HI = 2.2 ILCR = 2.0×10^{-5} (non-rad) ILCR = 7.3×10^{-4} (rad)	Dermal contact with soil, External gamma from soil, and Ingestion of groundwater
	Future Resident Farmer Adult (0 – 10 ft soil)	HI = 1.8 ILCR = 1.9×10^{-5} (non-rad) ILCR = 5.8×10^{-4} (rad)	Dermal contact with soil, External gamma from soil, and Ingestion of groundwater
	Future Resident Farmer Child (0 – 2 ft soil)	HI = 11 ILCR = 1.2×10^{-5} (non-rad) ILCR = 1.5×10^{-4} (rad)	Incidental soil ingestion, External gamma from soil, and Ingestion of groundwater
	Future Resident Farmer Child (0 – 10 ft soil)	HI = 8 ILCR = 1.2×10^{-5} (non-rad) ILCR = 1.2×10^{-4} (rad)	Incidental soil ingestion, External gamma from soil, and Ingestion of groundwater
Exposure Unit 3 (Off-site soils and Toussaint Creek tributaries)	Future Resident Farmer Adult (0 – 2 ft soil)	HI = 1.4 ILCR = 2.5×10^{-6} (non-rad) ILCR = 1.7×10^{-4} (rad)	External gamma from soil and Ingestion of groundwater
	Future Resident Farmer Adult (0 – 10 ft soil)	HI = 1.4 ILCR = 2.5×10^{-6} (non-rad) ILCR = 1.7×10^{-4} (rad)	External gamma from soil and Ingestion of groundwater
	Future Resident Farmer Child (0 – 2 ft soil)	HI = 4.4 ILCR = 1.1×10^{-6} (non-rad) ILCR = 3.7×10^{-4} (rad)	External gamma from soil and Ingestion of groundwater
	Future Resident Farmer Child (0 – 10 ft soil)	HI = 4.4 ILCR = 1.1×10^{-6} (non-rad) ILCR = 3.6×10^{-4} (rad)	External gamma from soil and Ingestion of groundwater
Exposure Unit 4 (Toussaint Creek)	Current/Future Adolescent Trespasser	HI = 0.07 ILCR = 1.4×10^{-6} (non-rad) ILCR = 5.9×10^{-9} (rad)	None
Exposure Unit 5 (France Stone Quarry)	Current/Future Adolescent Trespasser	HI = 0.00016 ILCR = 0 (non-rad) ILCR = 2×10^{-9} (rad)	None
Exposure Unit 6 (Troy Township Dump)	Current/Future Adolescent Trespasser	HI = 0 ILCR = 0 (non-rad) ILCR = 0 (rad)	None – Note no COPCs were identified so no risk calculations were performed

Table 2.5. Preliminary Constituents of Concern Identified in the Baseline Human Health Risk Assessment

Exposure Unit	Medium	COCs
Exposure Unit 1 (On-site undisturbed soils)	Soil	Benzo(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Dibenz(a,h)anthracene, Indeno(1,2,3-cd)pyrene, Aroclor-1254, Radium-226, Thorium-230, Uranium-234, Uranium-235, and Uranium-238
	Groundwater	Manganese, Uranium-234, Uranium-235, and Uranium-238
Exposure Unit 2 (On-site disturbed soils)	Soil	Benzo(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Indeno(1,2,3-cd)pyrene, Beryllium, Cadmium, Lead, Radium-226, Thorium-230, Uranium-234, Uranium-235, and Uranium-238
	Groundwater	Manganese, Uranium-234, Uranium-235, and Uranium-238
Exposure Unit 3 (Off-site soils and Toussaint Creek tributaries)	Soil	Beryllium , Protactinium-231, and Radium-226
	Groundwater	Manganese, Uranium-234, Uranium-235, and Uranium-238
	Sediment	Benzo(a)pyrene and Radium-226
Exposure Unit 4 (Toussaint Creek)	Sediment	Benzo(a)pyrene
Exposure Unit 5 (France Stone Quarry)	Soil	None
	Groundwater	None
Exposure Unit 6 (Troy Township Dump)	Soil	None
	Groundwater	None

Bolded COCs are retained as final COCs in Section 3 for purposes of this FS.

Total uranium in groundwater is retained as a final COC rather than the uranium isotopes as presented in the table.

Table 2.6. Preliminary Ecological Constituents of Concern Identified in the Screening Ecological Risk Assessment

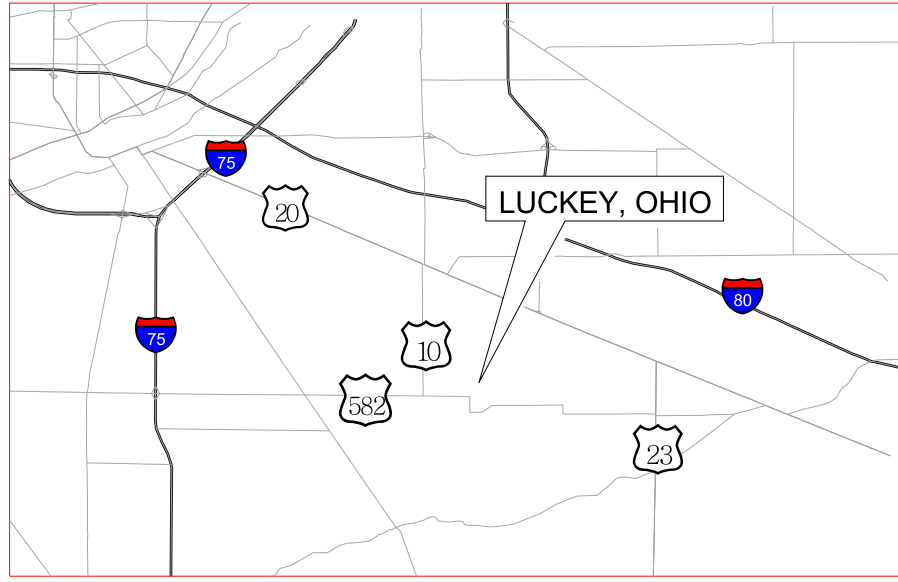
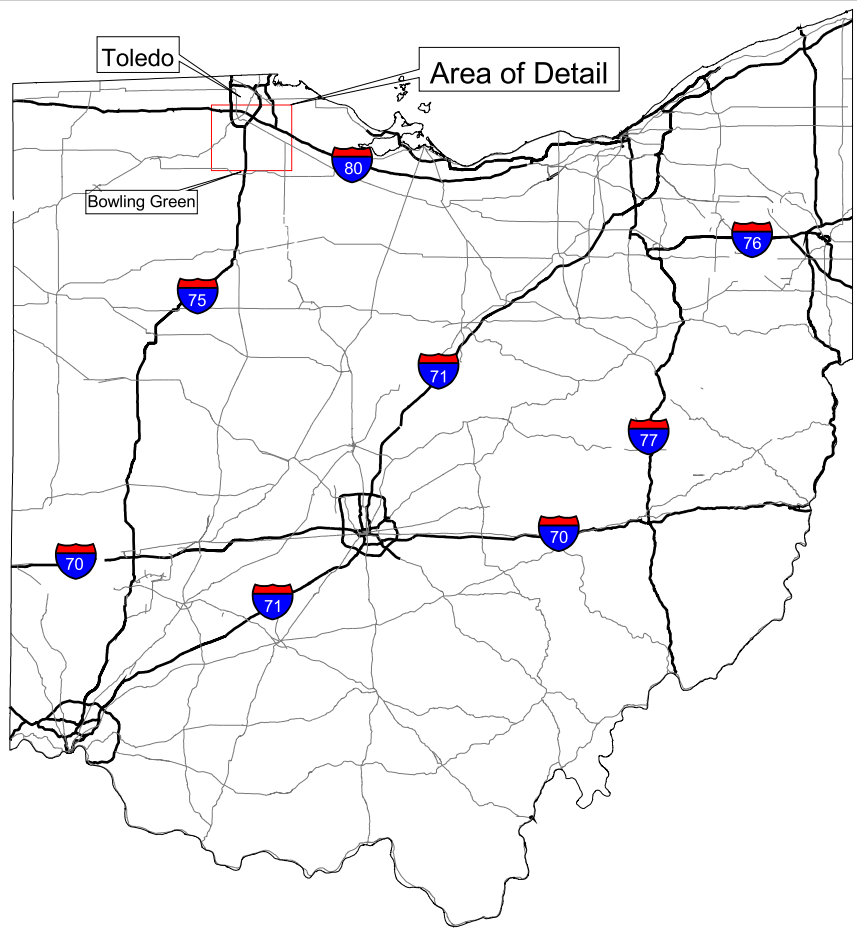
Exposure Unit	Medium	COCs
Exposure Unit 1 (On-site undisturbed soils)	Soil	Beryllium(7), Cadmium(12), Lead(277), Fluoride(2), Benzo(a)pyrene(3), and Aroclor-1254(201)
Exposure Unit 2 (On-site disturbed soils)	Soil	Beryllium(77), Boron(62), Cadmium(252), Chromium(127), Copper(1), Lead(175), Mercury(5), Nickel(2), Thallium(84), Zinc(29), and Fluoride(25)
Exposure Unit 3 (Off-site soils and Toussaint Creek tributaries)	Soil	Beryllium(16), Lead(94), and Selenium(3)
	Sediment	Cadmium(95), Copper(13), Iron(1100), Lead(11), Mercury(2), Nickel(3), Silver(5), and Zinc(5)
	Surface Water	Aluminum(12), Barium(47), Beryllium(16), Boron(147), Cadmium(1), Copper(2), Iron(2), Lead(18), Manganese(3), Mercury(7), Silver(2), Strontium(8), Fluoride(2000), and Bis(2-ethylhexyl)phthalate(2)
Exposure Unit 4** (Toussaint Creek)	Soil	Antimony(1), Beryllium(3), Cadmium(6), Lead(33), and Thallium(81)
	Sediment	Cadmium(46), Copper(1), Lead(17), and Silver(1)
	Surface Water	Aluminum(11), Barium(17), Boron(94), Iron(1), Lead(1), Manganese(8), Strontium(4), Fluoride(12), and Bis(2-ethylhexyl)phthalate(2)
Exposure Unit 5 (France Stone Quarry)	Soil	Lead(79)
Exposure Unit 6 (Troy Township Dump)	Soil	None

Maximum EEQ values are given in parentheses.

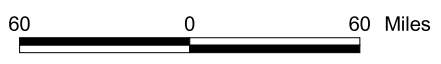
Calculation of an EEQ in a screening level ecological risk assessment is only a preliminary indication of ecological risk and the weight of evidence indicated absence of significant ecological impact (except for the bare spot).

**No COCs were identified in EU 4 in the Biological and Water Quality Study of Toussaint Creek and Select Tributaries (USACE 2002a).

S:\ARCVIEW LUCKEY\C01748\801\SITE LOCATION FS Report Fig No. 2.1



 Primary road with limited access
 Primary road



U.S. Army Corps of Engineers
Buffalo District



LUCKEY SITE

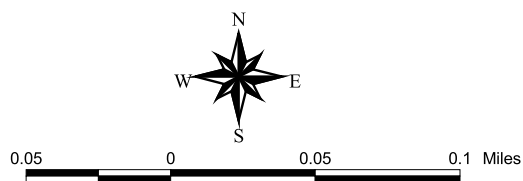
Site Location



Science Applications
International Corporation Columbus, Ohio

Drawn By LMA	Date 04-02-01	Scale As Shown	Project No. 04-1612-533	Figure No. 2.1
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S:\ARCVIEW\LUCKEY\GIS\PROJECT3\APR LAYOUT AERIAL PHOTO



U.S. ARMY CORPS OF ENGINEERS
BUFFALO DISTRICT
LUCKEY SITE



Luckey Site near Luckey, Ohio



Science Applications
International Corporation

Columbus, Ohio

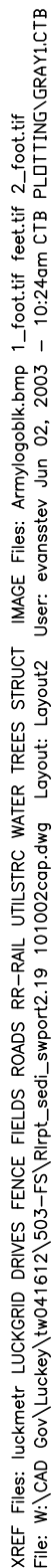
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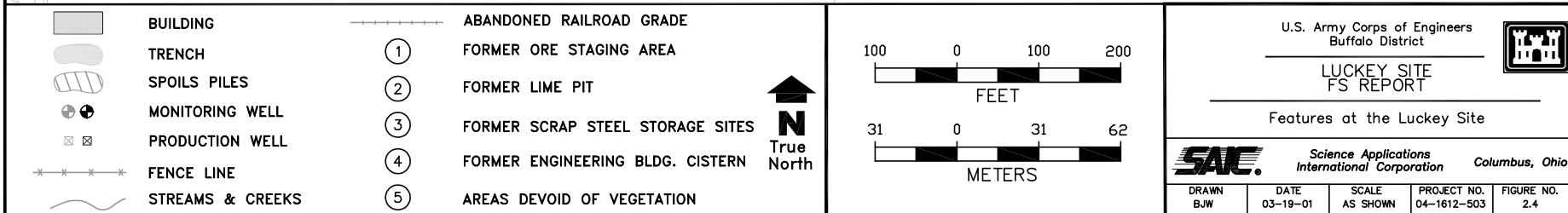
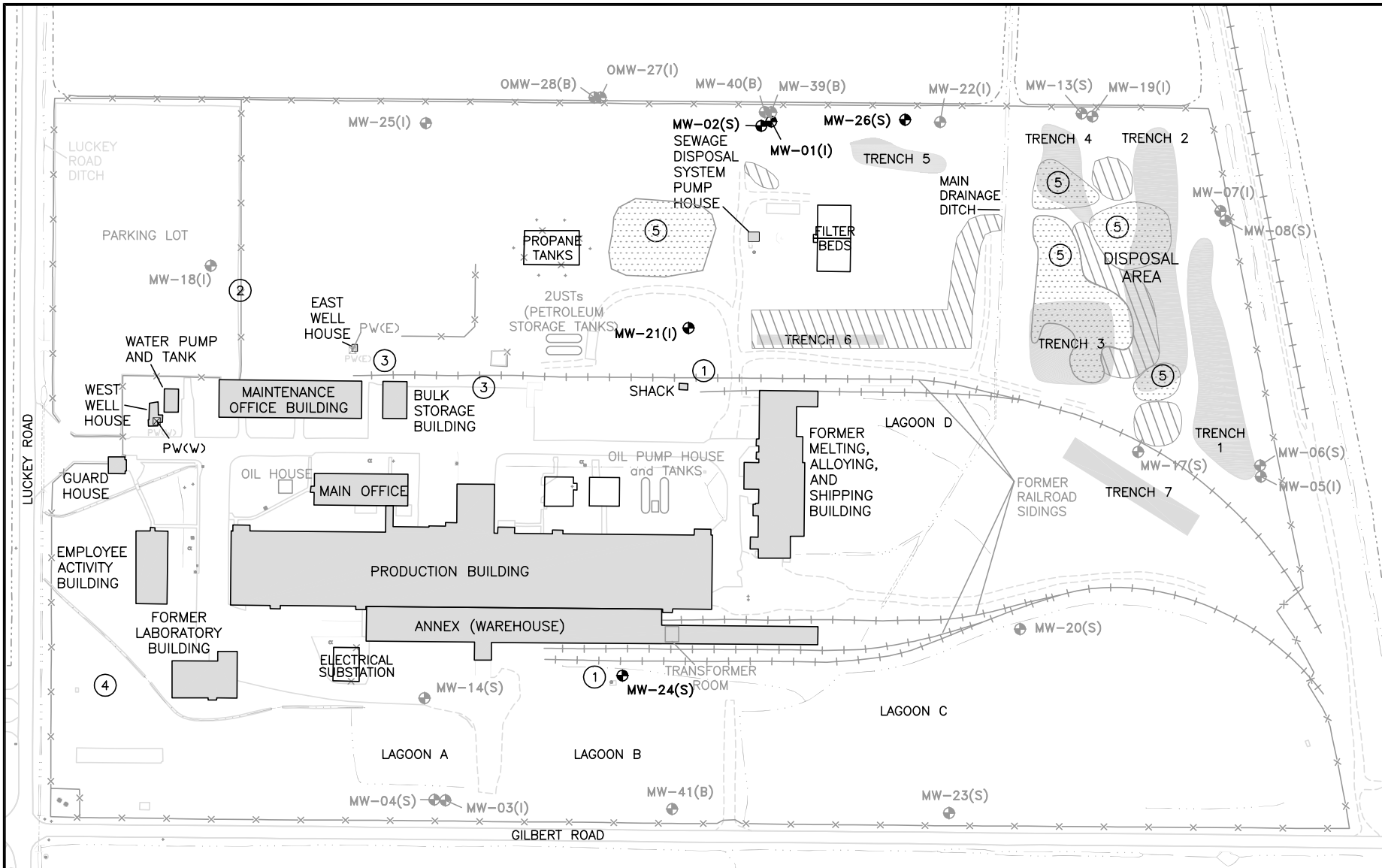
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Scale
As Shown

PROJECT NO.
04-1612-533

Figure NO.
2.2





XREF Files: IMAGE Files: 2_foot.tif Armylogobk.bmp feet.tif
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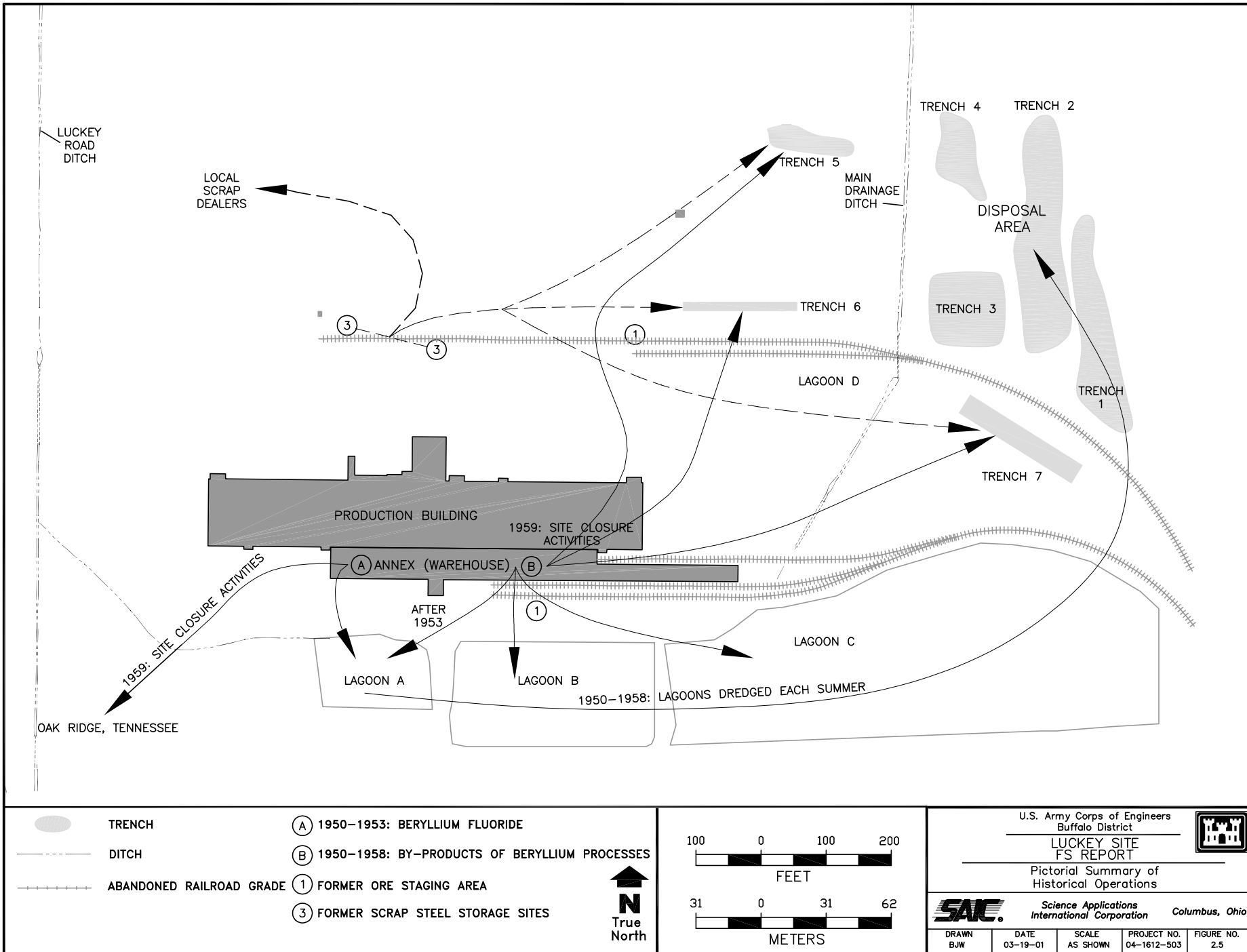


Figure 2.6. MW-01(I) Water Level and Beryllium Concentrations

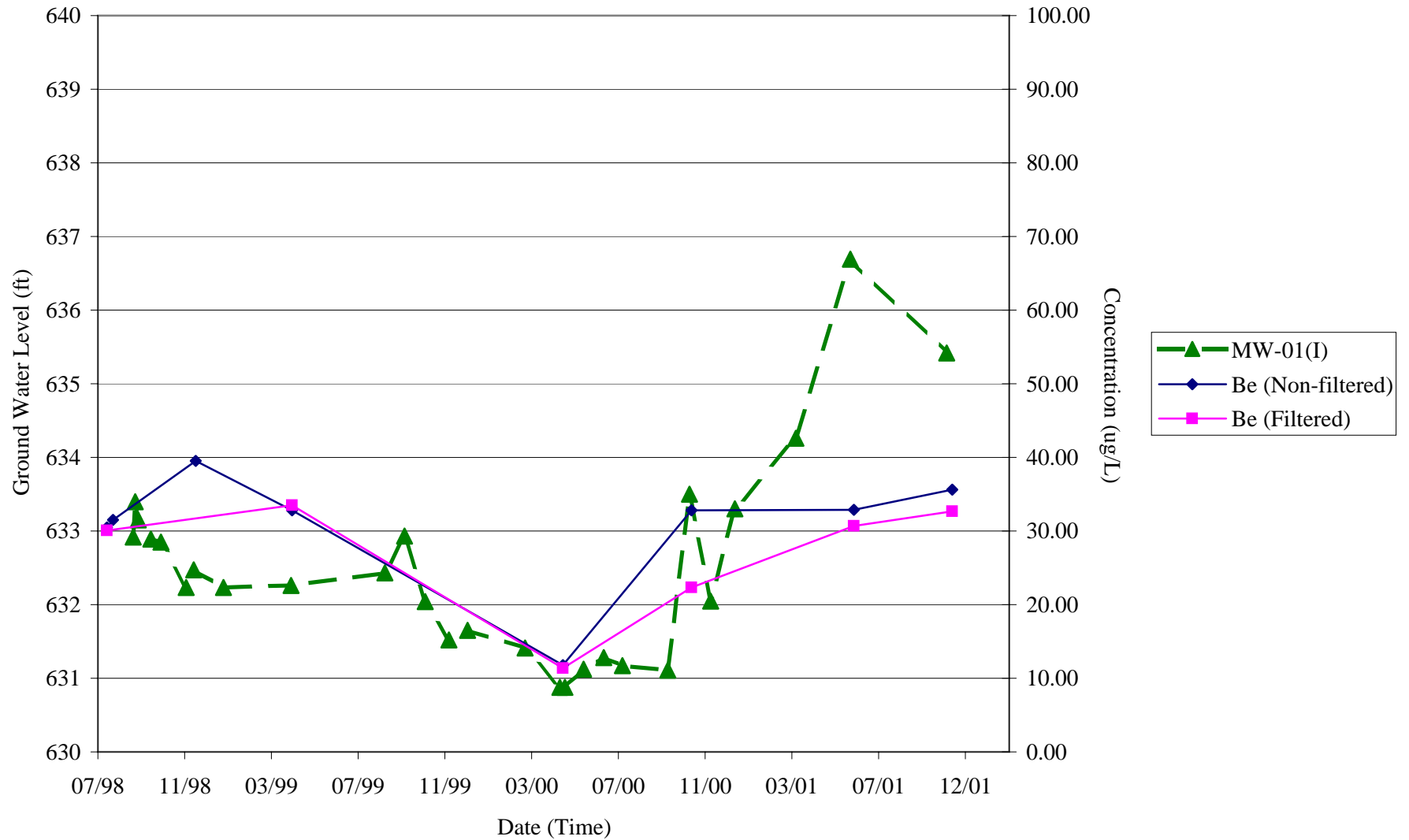


Figure 2.7. MW-02(S) Water Level and Beryllium Concentrations

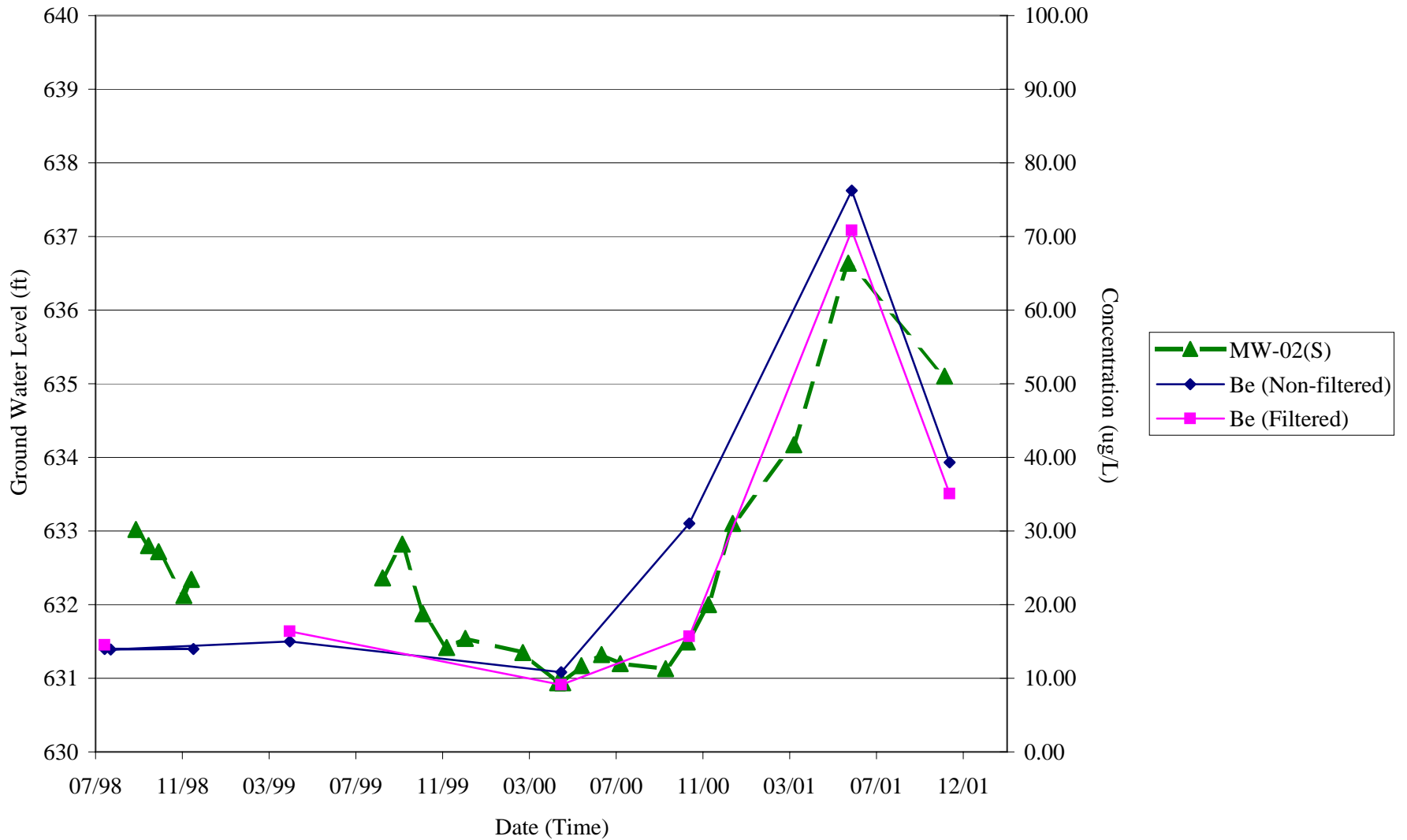


Figure 2.8. MW-21(I) Water Level and Lead Concentrations

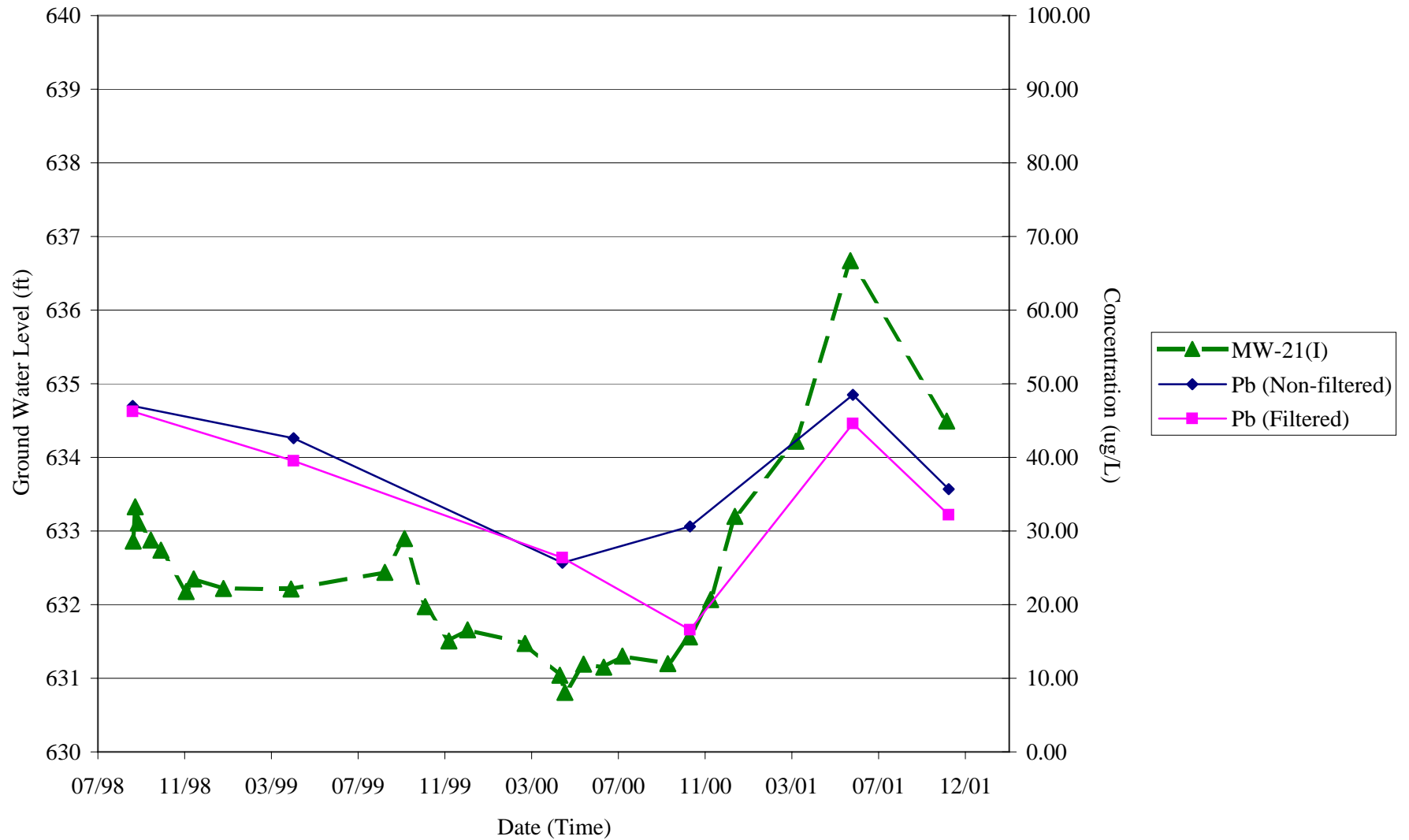
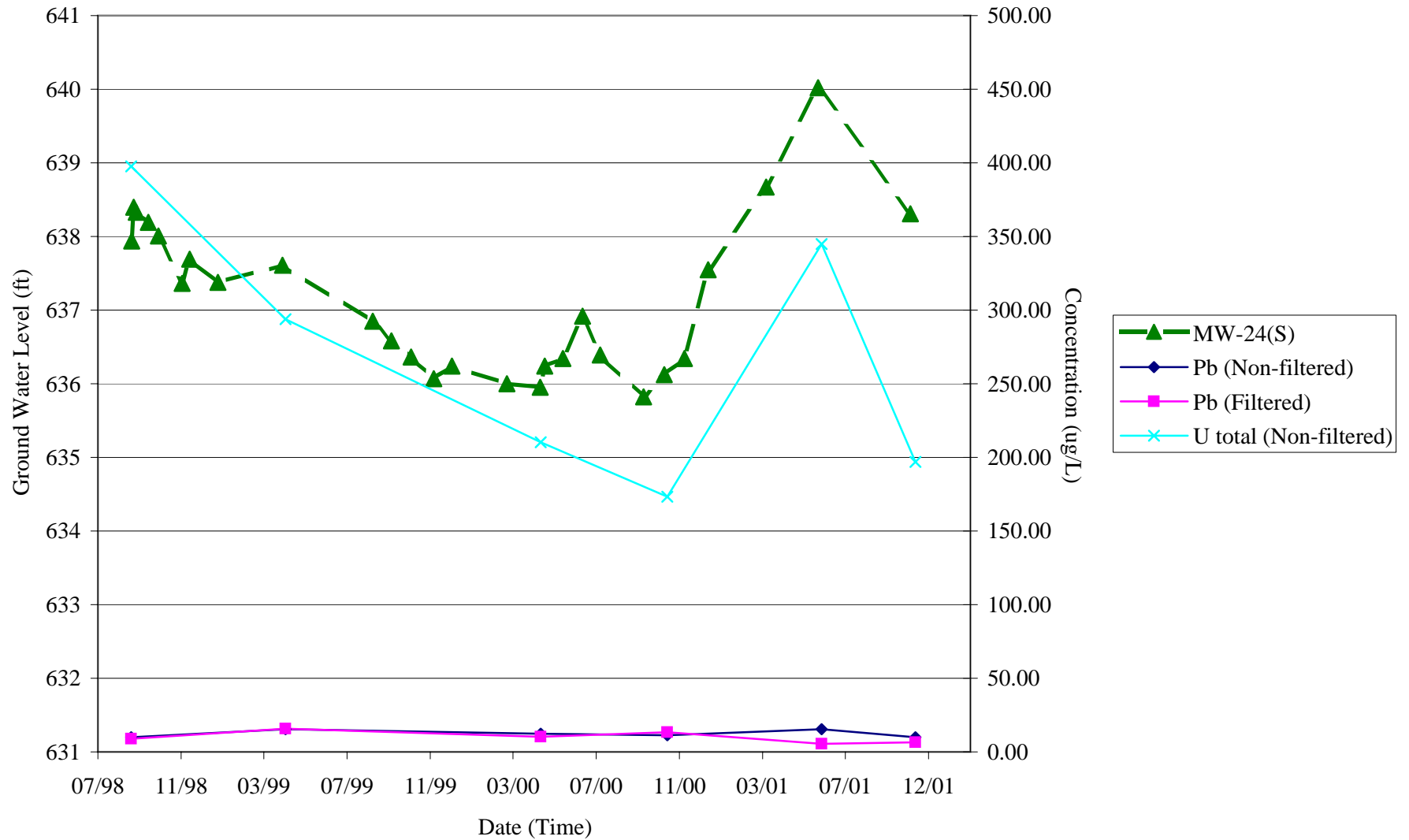


Figure 2.9. MW-24(S) Water Level and Lead, Total Uranium Concentrations



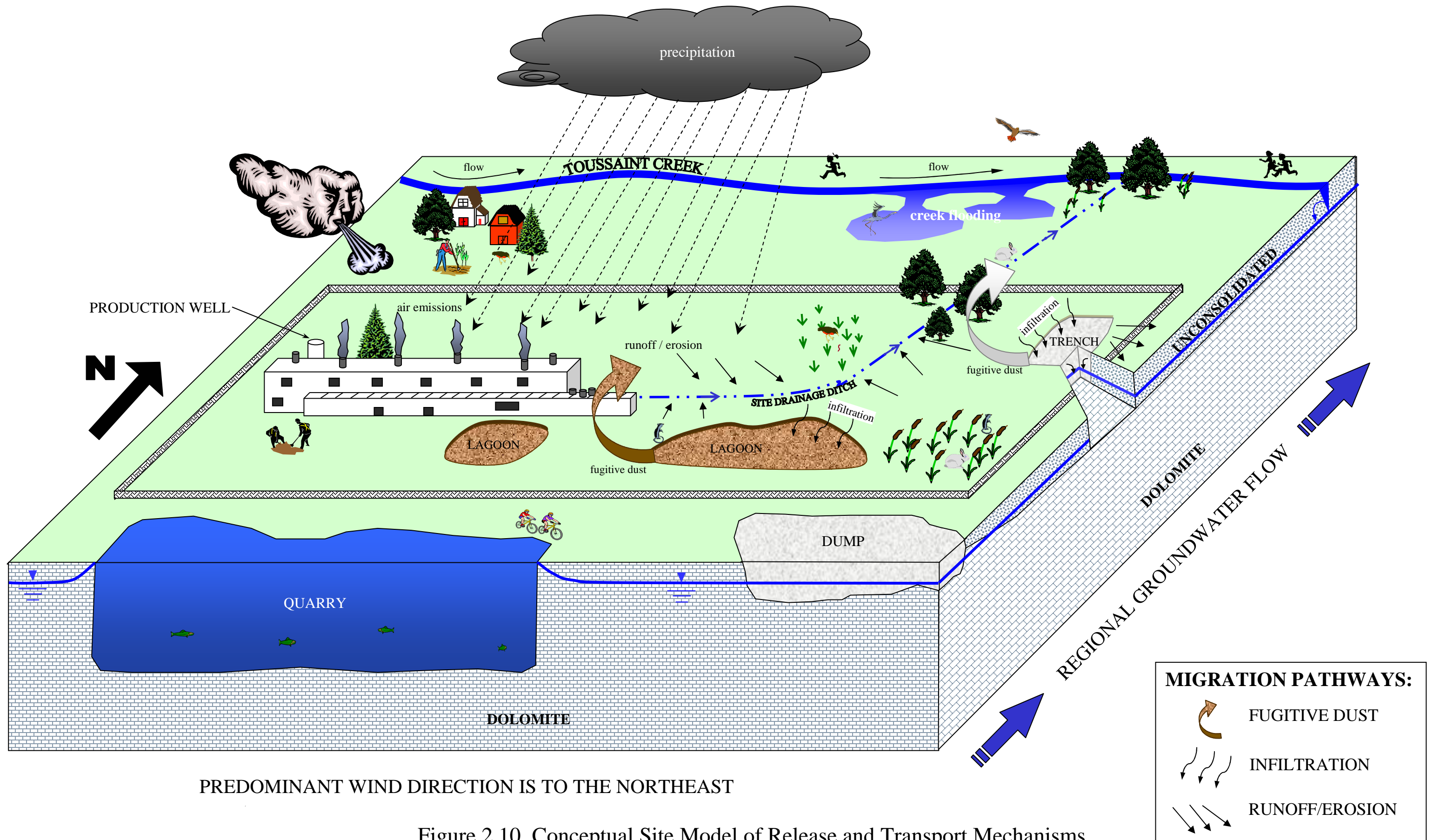


Figure 2.10 Conceptual Site Model of Release and Transport Mechanisms

3.0 REMEDIAL ACTION OBJECTIVES

This section of the FS describes the RAOs for the Luckey site. RAOs specify the requirements that remedial alternatives must fulfill in order to protect human health and the environment from contaminants and provide the basis for identifying and evaluating remedial alternatives in Sections 4, 5, and 6.

The RAOs for the Luckey site are intended to provide for long-term protection of human health and the environment. In order to provide this protection, media-specific objectives that identify major contaminants and associated media-specific cleanup goals are developed. These objectives specify the final COCs, the exposure routes and receptors, and an acceptable contaminant concentration for the long-term protection of receptors. The BRA for the Luckey site is summarized in Section 2 of this FS Report and detailed in Sections 6 and 7 of the Final RI Report (USACE 2000a).

The BRA includes baseline risk calculations for a number of receptors including a resident farmer and an industrial worker. Subsequent meetings between site planners and stakeholders resulted in the introduction of an additional, more conservative receptor based on the 10 Code of Federal Register (CFR) Part 20 Subpart E and OAC 3701:1-38-22 requirement to evaluate the “critical group” for radionuclides. In Ohio, the critical group for unrestricted land use has been consistently defined as the subsistence farmer. The subsistence farmer is assumed to represent the critical group at the Luckey site for unrestricted land use and is the subject of Appendix 3A. Appendix 3A addresses the risk calculations and revised cleanup goals resulting from the evaluation of the subsistence farmer scenario. Although not required by 10 CFR Part 20 Subpart E and OAC 3701:1-38-22, chemical constituents also were evaluated using the subsistence farmer scenario. In addition to unrestricted land use, this FS also considers current/future industrial use of the site (e.g. restricted land use). A more recent version of RESRAD (RESRAD 6.1) was used to evaluate radiological exposures to the subsistence farmer and a few RESRAD modeling parameters also were adjusted based on subsequent stakeholder input. RESRAD modeling of radiological exposures to the industrial worker also were revised to be consistent, as appropriate, with that used to evaluate the subsistence farmer. This revised risk assessment for the industrial worker scenario also is presented in Appendix 3A. The results of these evaluations for the subsistence farmer and revised industrial worker are incorporated into the RAOs.

Current land use at the Luckey site is industrial and is expected to remain industrial for the near future. The property is currently zoned M-1, light industrial. Wood County has a comprehensive plan (Wood County 1998) for Troy Township that acts as a guide for zoning and future use. It states that the property is an expansion area for the Village of Luckey, indicating that the village is slated to grow into the area. Given the current zoning designation, the most likely future expansion use for the property is industrial or commercial. However, it is possible future land use could be residential or agricultural for the following reasons: surrounding land use on three sides is agricultural and residential; agricultural and residential are the dominant land uses in Troy Township; there is no other industry in the area; and industrial facilities at the site are aging. The most recent deed to the property (a quitclaim deed from Goodyear on April 1, 1987) lists no specific restrictions or easements that would preclude residential or agricultural land use. As a result, COCs and media-specific cleanup goals are presented for both the industrial worker and subsistence farmer receptors.

The following sections present the development of the RAOs. Section 3.1 presents the RAOs for the Luckey site. The final COCs are identified in Section 3.2. Media-specific cleanup goals are presented in Section 3.3. Subsequent to the determination of media-specific cleanup goals, the extent of contamination and a corresponding volume of the impacted medium can be estimated. Section 3.4 summarizes the development of volume estimates for each of the land use scenarios.

3.1 REMEDIAL ACTION OBJECTIVES

In the baseline risk assessment developed in the RI Report, the site was divided into EUs for the purpose of evaluating risks to various receptors. RAOs are developed in this FS for the following units:

- Impacted Soils (on-site and off-site soils/EUs 1, 2, and 3)
- Site-Wide Groundwater (EU 7 within the confines of EUs 1, 2, and 3).

Contaminated off-site (EU 3) soils requiring remediation are generally contiguous with contaminated on-site soils (EUs 1 and 2). Therefore, for the identification and evaluation of RAOs and remedial alternatives, these have been combined into one unit collectively named “Impacted Soils.”

3.1.1 Impacted Soils and Groundwater

The Impacted Soils unit is predominantly an industrial property. A small portion is in an agricultural field. In the future, the land may remain industrial or become completely agricultural similar to surrounding land uses. In addition, terrestrial areas at the site are not currently managed for ecological purposes, nor are there any plans to manage these areas for ecological purposes in the future. These current and future land uses will allow for minimal habitat for ecological receptors and thus minimal exposure to ecological receptors. Therefore, final COCs have been identified for the protection of human health only. Addressing these final COCs also will reduce risks to ecological receptors. In addition, measures will be taken to prevent releases to the environment and impacts such as habitat disturbance during remedial alternative implementation. Exposure to constituents in groundwater is limited to human receptors. Therefore, RAOs will be developed to address final COCs that pose risks to human health only for these units. Addressing these risks also will reduce risks to ecological receptors.

The human health risk assessment evaluated risks to future receptors from constituents in soils from zero to 2 ft and zero to 10 ft bgs. The evaluation of the depth interval from zero to 10 ft bgs assumed that soil at depth could be brought to the surface during future excavation of a basement or building footers. For this FS, final COCs identified in either interval are addressed.

The RAOs for the Impacted Soils and Groundwater units are as follows:

- Remove or prevent exposure to media containing concentrations of COCs that may pose a risk to human health in excess of a 10^{-4} incremental lifetime cancer risk and/or non-cancer hazard index of 1. Final COCs are limited to constituents associated with AEC activities.
- Minimize the transport of soil COCs to other environmental media (groundwater, surface water, sediment, and air).
- Monitor, control, or actively reduce COCs in groundwater to ensure that, within a limited period of time, concentrations of these constituents are reduced to or below the media-specific cleanup goals at an established point of compliance. The point of compliance and time period to achieve compliance will comply with federal and state law.
- Restore the site to a condition consistent with its current and anticipated future uses.
- Prevent releases and other impacts that could adversely affect ecological receptors during implementation of the remedial alternative(s).
- Comply with ARARs.

3.2 CONSTITUENTS OF CONCERN

The final COCs addressed in this FS were identified as exceeding risk-based criteria or ARAR-based standards (e.g., MCLs) and are limited to constituents associated with AEC activities. Final COCs

will be the focus of the remedial effort evaluated in this FS. In Section 6 of the RI Report (USACE 2000a), human health risks were evaluated against risk-based goals established by CERCLA. For non-carcinogens, acceptable exposure levels are concentrations that do not exceed an HI of 1. The risk-based acceptable range for carcinogenic compounds has been established at 10^{-4} to 10^{-6} ILCR. In this evaluation, total ILCR from non-radiologicals will be considered separately from radiologicals because the cancer slope factors used to quantify cancer potential were developed differently for the two classes of compounds (USACE 1999b).

For this FS, chemical and radiological constituents are identified as final COCs if they contribute significantly to total risk (i.e., the concentration or activity must be reduced in order to reduce total ILCR below target levels). All exposure pathways evaluated in the BRA are considered in this evaluation (i.e., ingestion, dermal contact, external gamma, and inhalation of fugitive dust and volatiles). In addition, food intake pathways for the subsistence farmer scenario (Appendix 3A) are considered. In the BRA, preliminary COCs were chosen based on a cancer risk limit of 10^{-6} per pathway, where total risk per exposure unit was greater than 10^{-5} . These target risk limits were used in identifying preliminary COCs in the BRA, as per guidance from Ohio EPA. For this FS, a risk management decision was made to only consider COCs that contributed the most to risk. For cancer risk, constituents that contribute greater than 10^{-5} ILCR for any receptor (within an EU where cumulative cancer risks are greater than 10^{-4}) are considered significant and therefore are final COCs that will be addressed in this FS. For non-cancer risk, constituents that contribute an HI of 1 or greater (individually or in combination with other constituents) for a particular target organ are considered final COCs that will be addressed in this FS. Table 3.1 lists the final AEC-related COCs identified in soils as exceeding risk criteria. For the current receptor, the industrial worker, lead in soil is the only final AEC-related COC exceeding risk criteria. For the future subsistence farmer receptor, AEC-related soil COCs include beryllium, lead, radium-226, thorium-230, uranium-234, and uranium-238. Final Soil COCs contributing most significantly to risk are collocated with less significant risk drivers. Specifically, addressing the most significant contributors to risk also will mitigate risks from other (minor) soil COCs. No AEC-related COCs exceeded risk criteria in groundwater.

In the context of human health risks, 10^{-5} is a shorthand description for an increased lifetime chance of one in 100,000 of developing cancer due to lifetime exposure to a substance. The carcinogenic cancer threshold of 10^{-5} falls within the acceptable risk range of 10^{-4} to 10^{-6} specified by the NCP (EPA 1990). The risk level 10^{-5} is less than our current risk of developing cancer from background exposure to environmental contaminants, which has been estimated at 10^{-3} to 10^{-2} (Kelly and Cardon 1991). Personal lifestyle decisions such as smoking, the consumption of high fat diets, and exposure to sunlight contribute to cancer risk. In addition, some inherited genes can predispose some individuals to a very high risk of developing specific cancers. In the US, men have a little less than 1 in 2 (5×10^{-1}) lifetime risk of developing cancer from all sources, and for women the risk is a little more than 1 in 3 or 3×10^{-1} [American Cancer Society (ACS) 2002]. In 1991 EPA issued a memorandum to clarify the Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions (EPA 1991b). This Office of Solid Waste and Emergency Response Directive states that where cumulative carcinogenic site risk to an individual based on reasonable maximum exposure is less than 10^{-4} , and the non-carcinogenic HI of less than 1, action is generally not warranted unless the potential for adverse environmental impacts exists. Therefore, the use of target risk levels of total pathway cancer risks not to exceed 10^{-4} (and individual constituent risks not to exceed 10^{-5}) or a non-cancer risk threshold of an HI not to exceed 1 are believed to be protective of human health.

The potential for AEC-related constituents to leach from soils to groundwater was evaluated using the Seasonal Soil Compartment Model (SESOIL) [General Sciences Corporation (GCS) 1998]. SESOIL and RESRAD modeling results indicate AEC-related constituents do not leach through the clay-rich tills at concentrations exceeding risk- or ARAR-based cleanup goals using realistic distribution

coefficients, or Kd values (Appendix 6A). The models indicate uranium will leach to groundwater at concentrations above the uranium cleanup goal when a Kd of 15 is used, however, this is not a realistic Kd value for the site. Beryllium, lead, and uranium have been detected in groundwater at concentrations exceeding ARAR-based standards (most likely as a result of direct interaction between impacted soils and groundwater) and therefore are identified as final COCs. These constituents were not identified as exceeding acceptable risk criteria in groundwater in the BRA nor in the evaluation presented in Appendix 3A.

3.3 MEDIA-SPECIFIC CLEANUP GOALS

There are three potential sources of media-specific cleanup goals: concentrations based on site-specific background data, ARARs, and RBCs. Each of these sources is discussed below. The selected media-specific cleanup goals are presented in Section 3.3.4.

3.3.1 Background Concentrations

In the Luckey RI Report, background concentrations for naturally-occurring inorganic compounds and radionuclides are represented as the lower of the 95% upper tolerance limit (UTL) or the maximum detected concentration in background samples (see Sections 3.3 and 6.2.2 of the RI Report). If background concentrations exceed ARARs and RBCs, then background concentrations are used as the media-specific cleanup goals. For the units evaluated in this FS, ARARs or RBCs exceed background concentrations for all final COCs. Therefore, background concentrations have not been selected as media-specific cleanup goals for any final COCs.

3.3.2 Applicable or Relevant and Appropriate Requirements

Agencies responsible for remedial actions under CERCLA must ensure that selected remedies meet ARARs. The following sections describe the proposed ARARs for cleanup of the Luckey site.

3.3.2.1 Definitions

Applicable requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations published by the federal government, or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site.

Regulatory standards are promulgated for specific types of activities at particular kinds of facilities. Regulatory standards are thus limited in jurisdictional scope. If a regulatory standard would be legally enforceable against the facility under the circumstances of the release absent the CERCLA action, then the regulatory standard is applicable to the CERCLA action.

Relevant and appropriate requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria or limitations published by the federal government, or state environmental or facility citing laws that, while not “applicable” to a hazardous substance, pollutant, contaminant, remedial action, location or other circumstance at a CERCLA site, nonetheless address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is suited to the particular site.

Determining whether a rule is relevant and appropriate is a two-step process that first involves determining whether the rule is relevant, and, if so, whether it is appropriate. A requirement is relevant if it addresses problems or situations sufficiently similar to the circumstances of the remedial action

contemplated. It is appropriate if it is well suited to the site. In determining whether a requirement is both relevant and appropriate, the following factors may be considered:

- The purpose of the requirement and the purpose of the CERCLA action
- The medium regulated or affected by the requirement and the medium contaminated or affected at the CERCLA site
- The substances regulated by the requirement and the substances found at the CERCLA site
- The actions or activities regulated by the requirement and the remedial action contemplated at the CERCLA site
- Any variances, waivers, or exemptions to the requirement and their availability for the circumstances at the CERCLA site
- The type of place regulated and the type of place affected by the release or CERCLA action
- The type and size of structure or facility regulated and the type and size of structure or facility affected by the release or contemplated by the CERCLA action
- Any consideration of use or potential use of affected resources in the requirement and the use or potential use of the affected resource at the CERCLA site.

In addition to applicable or relevant and appropriate requirements, the lead agency may, as appropriate, identify other advisories, criteria, or guidance to be considered for a particular release. The “to be considered” (TBC) category consists of advisories, criteria, or guidance developed by federal agencies or states that may be useful in developing CERCLA remedies.

State standards that are promulgated, are identified by the state in a timely manner and are more stringent than federal requirements, may be applicable or relevant and appropriate. For purposes of identification of state standards, the term “promulgated” means that the standards are of general applicability and are legally enforceable.

USACE has determined the cleanup ARARs for remedial activities at the Luckey site include 10 CFR Part 20 Subpart E, OAC 3701:1-38-22, and SDWA MCLs.

3.3.2.2 10 CFR Part 20 Subpart E – Radionuclides

10 CFR Part 20 Subpart E is applicable to NRC licensed facilities. The regulation was promulgated by the NRC to ensure consistent standards for determining the extent to which lands must be remediated at facilities before remediation can be considered complete and the NRC license terminated. The Luckey site does not have a NRC license. Therefore, the rule is not applicable.

10 CFR Part 20 Subpart E is relevant and appropriate at the Luckey site. The regulation applies to any facility licensed by the NRC to manage special nuclear, source or byproduct radionuclide material that is undergoing decontamination and remediation for release of the property for reuse. Luckey is an industrial facility undergoing decontamination to remove radioactive residuals in order to release the property for reuse. The radioactive residuals at the Luckey site are residuals of uranium ore, naturally occurring uranium in the beryllium ore, and/or residuals from contaminated scrap metal sent to the site during AEC activities. In addition, the type and size of the Luckey facility is consistent with the type and size of facility regulated by 10 CFR Part 20 Subpart E and the media to be remediated and radioactive constituents of concern at Luckey are generally the same or similar to those found at sites subject to the regulation. The standards in the 10 CFR Part 20 Subpart E are:

- Unrestricted use: total effective dose equivalent (TEDE) limited to 25 millirem per year (mrem/yr) for the unrestricted land use receptor and demonstrated to be as low as reasonably achievable (ALARA).

- Restricted use: 25 mrem/yr TEDE to the restricted land-use receptor, ALARA, durable land use controls, license termination plan (LTP), public input, and 100 mrem/yr or 500 mrem/yr to the unrestricted land use receptor if land use controls fail.
- Alternate criteria: 100 mrem/yr, ALARA, LTP, and EPA and public input.

In summary, 10 CFR Part 20 Subpart E is both relevant and appropriate for use in the development of media-specific cleanup goals at the Luckey site. The rule addresses situations sufficiently similar to the circumstances of the release at Luckey and its use is appropriate to the circumstances of the release. The rule requires evaluation of the “critical group,” which in Ohio has been consistently defined as the subsistence farmer scenario for unrestricted use scenarios. This receptor group was not evaluated in the BRA presented in the RI Report; therefore, this evaluation is presented in Appendix 3A. Table 3.2 defines the cleanup goals for radionuclides based on 10 CFR Part 20 Subpart E. Activities listed in the table correspond to a dose of 25 mrem/yr for unrestricted land use and restricted land use with durable land use controls (activities address 100 mrem/yr for restricted use with loss of land use controls). If a mixture of radionuclides is present, then the sum of ratios applies.

3.3.2.3 OAC 3701:1-38-22 – Radionuclides

OAC 3701:1-38-22 contains limitations for radionuclides similar to those found in 10 CFR Part 20 Subpart E. The requirement has been promulgated by the State of Ohio, as an agreement state, to ensure consistent standards for determining the extent to which lands in the State of Ohio must be remediated before decommissioning of a site can be considered complete and the state license can be terminated. OAC 3701:1-38-22 is applicable to state-licensed facilities. The Luckey site has no state license; therefore, the regulation is not applicable at the Luckey site.

A state requirement can be an ARAR if it is more stringent than a federal standard; if it is identified in a timely manner; and if it is implemented consistently within the state. OAC 3701:1-38-22 contains the same provisions as 10 CFR Part 20 Subpart E, but one of those provisions is interpreted in a manner that is more stringent than the federal standard. OAC 3701:1-38-22 establishes a standard for unrestricted release of property of 25 mrem/yr plus ALARA, as the total effective dose equivalent to an average member of a critical group. “Critical group” is defined as “the group of individuals reasonably expected to receive the greatest exposure to residual radioactivity for any applicable set of circumstances.” (OAC 3701:1-38-01(A)(35)) In Ohio, the critical group has been consistently defined as the subsistence farmer. This practice is more stringent than that under 10 CFR Part 20 Subpart E. As OAC 3701:1-38-22 is not applicable to the Luckey site, as explained in the previous paragraph, the more stringent interpretation is relevant and appropriate to the Luckey site.

3.3.2.4 Maximum Contaminant Levels - Uranium and Beryllium in Groundwater

The MCLs promulgated pursuant to the SDWA are enforceable standards developed to protect human health from identified adverse effects of drinking water contaminants. The MCL for uranium is found at 40 CFR § 141.66(e) as published in 65 FR 76708-76748, December 7, 2000 and the MCL for beryllium is found at 40 CFR § 141.62(b) and the OAC at 3745-81-11(B). The Federal MCL for uranium has been established at 30 µg/L. The Federal MCL for beryllium is the same as the State of Ohio drinking water standard, at 4 parts per billion (ppb) or µg/L. MCLs apply to community water systems, defined as those that provide water directly to 25 or more people or supply 15 or more service connections. The system at the Luckey site supplies more than 25 people on a regular basis, so it is a community water system. However, MCLs apply when water comes out at the tap. At the Luckey site, the MCL is being used as a cleanup goal for groundwater and will be measured in the groundwater rather than when the water comes out of the tap. Therefore, the MCLs are not applicable to groundwater at the Luckey site.

The MCLs are relevant and appropriate to the Luckey site. MCLs generally are relevant and appropriate to the cleanup of groundwater that is or may be used for drinking because MCLs are the enforceable standards under the SDWA. The MCLs for carcinogens are within EPA's acceptable risk range, and MCLs are protective of human health. At the Luckey site, the MCL value is being cited as the target media-specific cleanup goal. Only the MCL value is being cited as relevant and appropriate. Other provisions of 40 CFR § 141.66, such as monitoring and reporting requirements, are not included. The monitoring and reporting requirements set forth in 40 CFR § 141.66 apply to community water systems that provide drinking water to consumers.

3.3.2.5 National Primary Drinking Water Regulations - Lead in Groundwater

An action level, under the SDWA, is the regulatory equivalent of an MCL for a drinking water contaminant. In requiring that National Pollution Drinking Water Regulations (NPDWRs) be established for drinking water contaminants, the SDWA provides that standards can be promulgated as MCLs or as treatment techniques. The lead NPDWR health standard found at 40 CFR § 141.80(c) and OAC 3745-81-80(C)(1) is promulgated as a treatment technique, with a trigger action level of 0.015 mg/L.

MCLs are usually used as ARARs for cleanup of contaminated groundwater. As stated in the previous paragraph, the lead action level is equivalent to an MCL for lead. The lead action level would be applicable to water as it comes out of the tap. Groundwater is not water that comes out of the tap; therefore, the lead action level is not applicable to groundwater, but is relevant and appropriate for a groundwater cleanup level at the Luckey site. At the Luckey site, the action level is being cited as the target media-specific cleanup goal for lead in groundwater, and will be measured in the groundwater rather than when the water comes out of the tap.

At the Luckey site, the action level is being cited as the target media-specific cleanup goal. Only the action level is being cited as relevant and appropriate. Other provisions of 40 CFR § 141.80, such as monitoring and reporting requirements, are not included.

3.3.3 Risk-based Concentrations

The RBCs for the human health chemical COCs originally were developed in Section 6 of the RI Report in accordance with to the *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual, Part B* (EPA 1991a). These RBCs were developed to be protective of receptors under the resident farmer scenario, but have been modified to be protective of the subsistence farmer. Appendix 3A presents an evaluation of the RBCs for beryllium and lead with respect to food intake pathways that could be present under this scenario (i.e., a subsistence farmer scenario). RBCs for lead and beryllium are protective of a child receptor, which was identified in the BRA as being at greater risk from exposures to lead and beryllium than an adult receptor. These pathways were not evaluated quantitatively in the RI Report.

Lead does not have toxicological reference values because risks from exposure to lead are better evaluated by predicting the associated blood lead level. Blood lead levels have been accepted as the best measure of external lead dosing. Sensitive populations include preschool age children and fetuses. In these populations, a blood lead level of between 10 and 15 micrograms per deciliter (µg/dL) has been associated with a level at which no adverse effects would be expected. The approach used herein relates intake of lead from soil to blood lead concentrations in residential children and to women of child-bearing age who may be exposed to lead in soil while working at the site. Protection of a hypothetical fetus of an occupationally-exposed mother ensures other workers at the site also will be adequately protected.

A risk-based cleanup goal of 400 mg/kg lead in soil was established by EPA based on the *Revised Interim, Soil Lead Guidance for CERCLA sites RCRA Corrective Action Facilities* (EPA 1994). This concentration is supported by EPA's IEUBK for Lead in Children (EPA 2001). The IEUBK predicts that 400 mg/kg of lead in soil could cause a six year old resident child (averaged across the preceding 84 months) to have a probability of no greater than 5% of having a blood lead level of 10 µg/dL. For current and future resident farmer scenarios, the RBC for lead is 400 mg/kg.

The IEUBK model used to develop the 400 mg/kg lead in soil value accounts for a number of exposure pathways (other than direct exposures to soil) that can contribute to an individual's total lead exposure. One of these additional pathways is dietary lead intake. These default dietary intake values account for lead in various food products. While not specifically a subsistence farmer scenario, the default exposure scenario in the IEUBK model does account for the types of pathways one would evaluate for this receptor. In addition, according to the User's guide for IEUBK (EPA 2001), "Model predictions are not very sensitive to this parameter" - where "this parameter" refers to change in concentration of lead in food. Since this is not a very sensitive input parameter, there is no need to evaluate this pathway further for subsistence farmer (relative to resident farmer), where we might expect a higher concentration of lead in food produced in contaminated soils. Therefore, the 400 mg/kg is believed to be protective of receptors under a subsistence farmer scenario.

The non-residential RBC for lead was developed using EPA's lead model developed by the Technical Review Workgroup (TRW) (EPA 1996a). The TRW approach for assessing non-residential adult risks utilizes some basic algorithms to relate soil lead intake to blood lead concentrations in women of child bearing age. The basis for the calculation is the relationship between the concentration of lead in soil and the blood lead concentrations in a developing fetus of adult women that have occupational site exposures. In TRW model, the highest acceptable fetal blood lead level was set at the 95th percentile of 10 µg/dl, which is the concentration recommended by EPA and the Centers for Disease Control. The RBC for lead in soil for non-residential adults was calculated as 958 mg/kg. This value is believed to be protective of receptors under an industrial worker scenario.

The media-specific cleanup goal for beryllium is an RBC. The RBC for beryllium is based on the non-carcinogenic risk posed by this compound. For non-carcinogenic compounds, EPA has determined that acceptable exposure levels are concentrations that do not exceed an HI of 1. If multiple final COCs have similar toxic effects or target the same organ, then the total HI for these compounds must not exceed 1. Exposure to beryllium can cause intestinal lesions and berylliosis, a disease of the lungs. No other final COCs have similar toxic effects or target the same organs; therefore, the RBC for beryllium corresponds to an HI of 1. The cancer risk from exposure to beryllium at the RBC of 131 mg/kg is approximately 10⁻⁸.

In developing the RBC, the following exposure pathways were evaluated quantitatively: soil ingestion, dermal contact, and inhalation of fugitive dust. In addition, food intake pathways consistent with a subsistence farmer scenario were considered. Food intake pathways were evaluated quantitatively (ingestion of home-grown produce) and qualitatively (ingestion of meat, milk, and fish). Evaluation of the food pathways revealed that only plant uptake/consumption of home-grown produce contributed to risk from beryllium. Therefore, this pathway, along with soil ingestion, dermal contact, and inhalation of fugitive dust were used to calculate an RBC of 131 mg/kg beryllium in soil. This corresponds to an HI of 1. This calculation is discussed in more detail in Appendix 3A. The RBC was originally developed in the Section 6 of the RI Report (USACE 2000a) for a future resident farmer receptor and was subsequently revised for a subsistence farmer.

Ecological RBCs are not required for the units under evaluation in this FS for reasons stated in Section 3.1.1.

3.3.4 Selected Media-Specific Cleanup Goals

Tables 3.1 and 3.2 present the media-specific cleanup goals according to receptor. The media-specific cleanup goals for the Impacted Soils and Groundwater units are presented in Table 3.3. These goals will be used to develop the volume estimates for contaminated media and form the basis for confirmatory sampling.

The cleanup goals selected for impacted soils also were evaluated using SESOIL (GCS 1998) and RESRAD to evaluate their protectiveness of groundwater (Appendix 6A). SESOIL and RESRAD modeling results indicate, using realistic input parameters (e.g. distribution coefficients [Kd], hydraulic parameters), that AEC-related constituents do not leach through the clay-rich tills at concentrations exceeding their respective risk- or ARAR-based cleanup goals. For example, the models indicate uranium will leach to groundwater at concentrations above the cleanup goal when a Kd of 15 milliliters per gram (ml/g) is used. Further evaluation indicates background concentrations of uranium in soil also would leach to groundwater above the uranium cleanup goal when a Kd of 15 ml/g is used. Therefore, widespread concentrations of uranium in groundwater above the cleanup goal should occur if this were a realistic Kd value. Since this is not the case, a Kd of 15 ml/g is determined not to be realistic for the site. The SESOIL and RESRAD evaluation indicates concentrations in soils, at or below the cleanup goals, do not leach to groundwater at concentrations exceeding the drinking water standards and thus are protective of groundwater.

Note that the ARAR-based cleanup goals presented in Table 3.3 for radionuclides in soil correspond to a TEDE of 25 mrem/yr or 100 mrem/yr, depending on land use (unrestricted versus restricted). When multiple radionuclides are present, activities need to be adjusted so that the total activity does not exceed the TEDE. In other words, the soil cleanup goals presented in Table 3.3 assume only one of the radionuclides is present. An example of an adjustment for multiple radionuclides is provided in the footnotes to Tables 3.2 and 3.3. USACE utilizes the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) (DOD 2000) to assure combined exposure to all radiological COCs will not exceed the respective dose limit.

Cleanup goals are used in this FS to provide a basis for comparison of alternatives. They are not to exceed concentrations to generate a potentially conservative volume estimate. During implementation of the selected remedial alternative (including confirmatory sampling), cleanup goals will be used as target concentrations (e.g., 95% upper confidence limit of the mean) for the final COCs so no "hot spots" remain, potentially posing unacceptable risk. As indicated above, MARSSIM will be applied for radionuclides. Presentation of this cleanup confirmation methodology will occur in the detailed design document following approval of the proposed plan.

3.4 EXTENT AND VOLUME CALCULATIONS

After media-specific cleanup goals are determined, the extent of the contamination to be addressed and the associated volume in each medium can be estimated. Analytical data collected during the RI and ORNL investigations were used to generate a three dimensional volume model for each final AEC-related COC using a geologic modeling and geospatial visualization program. Beryllium and radiological screening data also were evaluated and included in the extent and volume estimates. The volume of soils exceeding cleanup goals for unrestricted land use and industrial land use are summarized in Tables 3.4 and 3.5, respectively. Supplemental information and data are presented in Appendix 3B.

The in situ volume of soil exceeding unrestricted land use cleanup goals is estimated at 55,400 cubic yards (cy) (Table 3.4 and Figure 3.1). Seventy-one percent of this total volume, or 39,200 cy, is

located in the disposal area in the northeast corner of the site and in Lagoons A, B, and C. The in situ volume of soil exceeding industrial land use cleanup goals is estimated at 30,050 cy (Table 3.5 and Figure 3.2). Seventy-six percent of this total volume, or 22,900 cy, is located in the disposal area in the northeast corner of the site and in Lagoons A, B, and C. These volume estimates represent in situ values and do not account for additional volume that may occur during excavation and expansion typically associated with soil removal. These factors, however, are taken into account for cost estimating purposes.

In addition to estimating the volume of soil exceeding clean-up goals, an estimate of the volumes of potential waste streams also was developed. Characteristics of the contaminated soils affect the final disposition of soils and determine applicable waste stream categories. Four categories of waste streams are potentially applicable: solid waste, FUSRAP radioactive waste, Resource Conservation and Recovery Act (RCRA) hazardous waste, and mixed waste. The term mixed waste, as used throughout this report for the Luckey site, is defined as *RCRA hazardous waste with radioactive residuals that are not NRC regulated*. This includes 1) RCRA hazardous wastes containing radioactive residuals at activities acceptable for disposal at a RCRA permitted disposal facility, and 2) RCRA hazardous waste containing radioactive residuals at activities requiring disposal at a RCRA disposal facility that is both permitted and licensed.

Solid waste, consisting of beryllium-contaminated soils, comprises the largest percentage of the estimated volume for unrestricted release at approximately 64%. Smaller percentages are represented by FUSRAP radioactive waste (~ 29%), mixed waste (~ 4.5%), and hazardous waste (~ 2.6%). These breakouts also are taken into account for cost estimating purposes. The estimated volume for industrial land use is assumed to be comprised almost entirely of FUSRAP radioactive waste.

At the Luckey site, detection of beryllium, lead, and uranium in groundwater above cleanup goals is limited to a few on-site monitoring wells [MW-01(I), MW-02(S), MW-13(S), MW-19(I), MW-21(I), MW-24(S), and MW-26(S)] (Figure 3.3). Data do not indicate a plume exists in the groundwater at Luckey for any of these constituents; therefore, a volume has not been estimated. Instead, groundwater transport scenarios were simulated to support evaluation of each of the alternatives presented in Section 5 to evaluate effectiveness and to estimate a timeframe to achieve cleanup goals in groundwater (Appendix 6A).

**Table 3.1. Final AEC-related COCs and Media-specific Cleanup Goals for Human Health
(Reasonable Maximum Exposure Scenarios)**

IMPACTED SOILS			
Receptors	COCs	Media-specific Cleanup Goal^a	Source
Current/Future Industrial Worker (0 – 2 ft.)	Lead	958 mg/kg	RBC
Future Subsistence Farmer (0 – 10 ft.)	Lead	400 mg/kg	RBC
	Beryllium	131 mg/kg ^b	RBC
	Radium-226	See Table 3.2	ARAR
	Thorium-230	See Table 3.2	ARAR
	Uranium-234	See Table 3.2	ARAR
	Uranium-238	See Table 3.2	ARAR
GROUNDWATER			
Receptors	COCs	Media-specific Cleanup Goal	Source
Current/Future Industrial Worker	Beryllium	4 µg/L	ARAR
	Lead	15 µg/L	ARAR
	Uranium (total)	30 µg/L	ARAR
Future Subsistence Farmer	Beryllium	4 µg/L	ARAR
	Lead	15 µg/L	ARAR
	Uranium (total)	30 µg/L	ARAR

^a SESOIL modeling results indicate risk-based and/or ARAR-based cleanup goals selected for soils are protective of groundwater.

^b HQ =1

Table 3.2. Dose-based Media-specific Cleanup Goals for Radionuclides

Receptor	Medium (units)	Radionuclide	Dose-based Media-specific Cleanup Goal (equal to 25 mrem/year) ^a	Dose-based Media-specific Cleanup Goal (equal to 100 mrem/year) ^a
Subsistence Farmer	Soil (pCi/g)	Radium-226	2.0	8.1
		Thorium-230 ^b	5.8	23
		Uranium-234 ^b	26	100
		Uranium-238 ^b	26	110
	Groundwater (pCi/L)	Uranium-238 ^c	200	--
Industrial Worker	Soil (pCi/g)	Radium-226	21	--
		Thorium-230 ^b	60	--
		Uranium-234 ^b	71	--
		Uranium-238 ^b	73	--
	Groundwater (pCi/L)	Uranium-238 ^c	310	--

**All values rounded to two significant digits.

^a Values shown to two significant digits – some round-off error may occur. Soil cleanup goals for radionuclides represent activity levels above site background activity corresponding to 25 mrem/yr (10 CFR Part 20 Subpart E and OAC 3701:1-38-22) or 100 mrem/yr for remedial alternatives that include loss of land use controls. If a mixture of radionuclides is present, then the sum of ratios applies per MARSSIM. For example, use the 25 mrem/yr unrestricted land use cleanup goals for soil to get the following sum of the ratios equation:

$$SOR = \frac{Ra - 226}{2.0 \text{ pCi/g}} + \frac{Th - 230}{5.8 \text{ pCi/g}} + \frac{U - 234}{26 \text{ pCi/g}} + \frac{U - 238}{26 \text{ pCi/g}}$$

where

SOR = sum of the ratios result

Ra-226 = net Ra-226 soil concentrations

Th-230 = net Th-230 soil concentrations

U-234 = net U-234 soil concentrations

U-238 = net U-238 soil concentrations

Net soil concentrations exclude background.

^b Th-230 value conservatively represents limit at year 1,000 allowing for ingrowth of Ra-226. Uranium values also represent limits at year 1,000 allowing for modeled infiltration to groundwater.

^c The federal drinking water standard for uranium is 27 pCi/L (corresponding to 30 µg/L) including the sum of all isotopes. Assuming that U-238 makes up 1 part per 2.046 of total uranium activity (for natural uranium), U-238 would be limited to approximately 13 pCi/L to meet the drinking water standard.

Table 3.3. Final AEC-related COCs and Selected Media-specific Cleanup Goals for Luckey Site

IMPACTED SOILS			
Receptors	COC	Media-specific Cleanup Goal ^a	Source
Current/Future Industrial Worker	Lead	958 mg/kg	RBC
	Radium-226	8.1 pCi/g ^{b,d}	ARAR
	Thorium-230	23 pCi/g ^{b,d}	ARAR
	Uranium-234	71 pCi/g ^{b,d}	ARAR
	Uranium-238	73 pCi/g ^{b,d}	ARAR
Future Subsistence Farmer	Beryllium	131 mg/kg	RBC
	Lead	400 mg/kg	RBC
	Radium-226	2.0 pCi/g ^{c,d}	ARAR
	Thorium-230	5.8 pCi/g ^{c,d}	ARAR
	Uranium-234	26 pCi/g ^{c,d}	ARAR
	Uranium-238	26 pCi/g ^{c,d}	ARAR
GROUNDWATER			
Receptors	COC	Media-specific Cleanup Goal ^a	Source
Current/Future Industrial Worker	Beryllium	4 µg/L	ARAR
	Lead	15 µg/L	ARAR
	Uranium (total)	30 µg/L	ARAR
Future Subsistence Farmer	Beryllium	4 µg/L	ARAR
	Lead	15 µg/L	ARAR
	Uranium (total)	30 µg/L	ARAR

^a SESOIL modeling results indicate risk-based and/or ARAR-based cleanup goals selected for soils are protective of groundwater.

^b These cleanup goals represent activity levels above site background activity corresponding to 25 mrem/yr or 100 mrem/yr (whichever corresponding activity is more conservative – refer to Table 3.2) for remedial alternatives that include loss of land use controls i.e. restricted land use.

^c These cleanup goals represent activity levels above site background activity corresponding to 25 mrem/yr.

^d If a mixture of radionuclides is present, then the sum of ratios applies per MARSSIM. For example, using the unrestricted land use cleanup goals for soil, the following sum of ratios equation is obtained:

$$SOR = \frac{Ra - 226}{2.0 \text{ pCi/g}} + \frac{Th - 230}{5.8 \text{ pCi/g}} + \frac{U - 234}{26 \text{ pCi/g}} + \frac{U - 238}{26 \text{ pCi/g}}$$

where

SOR = sum of the ratios result

Ra-226 = net Ra-226 soil concentrations

Th-230 = net Th-230 soil concentrations

U-234 = net U-234 soil concentrations

U-238 = net U-238 soil concentrations

Net soil concentrations exclude background.

Table 3.4. Estimated Volumes of Impacted Soils ~ Unrestricted Land Use

Zone	In situ Soil Volumes			Ex situ Soil Volumes	
	Total Volume Modeled from Data (cy) ¹ [a]	Potential Additional Volume (cy) [b]	Most Likely Volume In situ (cy) [a + b]	Ex situ Soil Volume (cy) (includes over-excavation, constructability, and swell)	Percentage of Ex situ Soil Volume
disposal area (IA01)	12,700	8,300	21,000	33,264	38%
Lagoon A (IA02)	300	0	300	475	<1%
Lagoon B (IA02)	5,500	1,400	6,900	10,930	12%
Lagoon C (IA02)	7,500	3,500	11,000	17,424	20%
Lagoon D/railroad sidings (IA03)	2,300	0	2,300	3,643	4%
soils surrounding buildings (IA04)	700	0	700	1,109	1%
filter bed area (IA05)	4,350	0	4,350	6,890	8%
northwestern portion of site (IA07)	4,350	0	4,350	6,890	8%
western portion of site (IA08)	100	0	100	158	<1%
off-site	4,400	0	4,400	6,970	8%
Total	42,200	13,200	55,400	87,754	

- 1) The "Total Volume Modeled from Data" was calculated using a software package named EarthVision™ developed by Dynamic Graphics, Incorporated (www.dgi.com) and the Minimum Tension Gridding Algorithm along with engineering judgment to confine and shape the modeled extents.

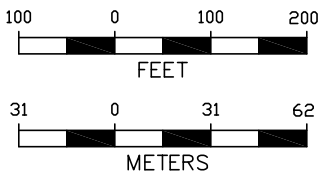
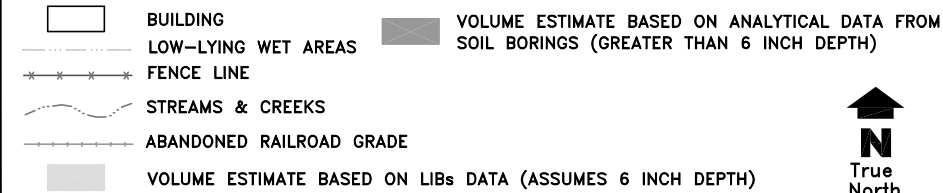
IA = Investigative Area

Table 3.5. Estimated Volumes of Impacted Soils ~ Industrial Land Use

Zone	In situ Soil Volumes			Ex situ Soil Volumes	
	Total Volume Modeled from Data (cy) ¹ [a]	Potential Additional Volume (cy) [b]	Most Likely Volume In situ (cy) [a + b]	Ex situ Soil Volume (cy) (includes over-excavation, constructability, and swell)	Percentage of Ex situ Soil Volume
disposal area (IA01)	4,950	10,700	15,650	24,790	52%
Lagoon A (IA02)	60	0	60	95	<1%
Lagoon B (IA02)	1,750	4,910	6,660	10,549	22%
Lagoon C (IA02)	500	0	500	792	2%
Lagoon D/railroad sidings (IA03)	80	2,800	2,880	4,562	10%
soils surrounding buildings (IA04)	0	0	0	0	0
filter bed area (IA05)	150	3,100	3,250	5,148	11%
northwestern portion of site (IA07)	1,050	0	1,050	1,663	3%
western portion of site (IA08)	0	0	0	0	0
off-site	0	0	0	0	0
Total	8,540	21,510	30,050	47,599	

- 1) The "Total Volume Modeled from Data" was calculated using a software package named EarthVision™ developed by Dynamic Graphics, Incorporated (www.dgi.com) and the Minimum Tension Gridding Algorithm along with engineering judgment to confine and shape the modeled extents.

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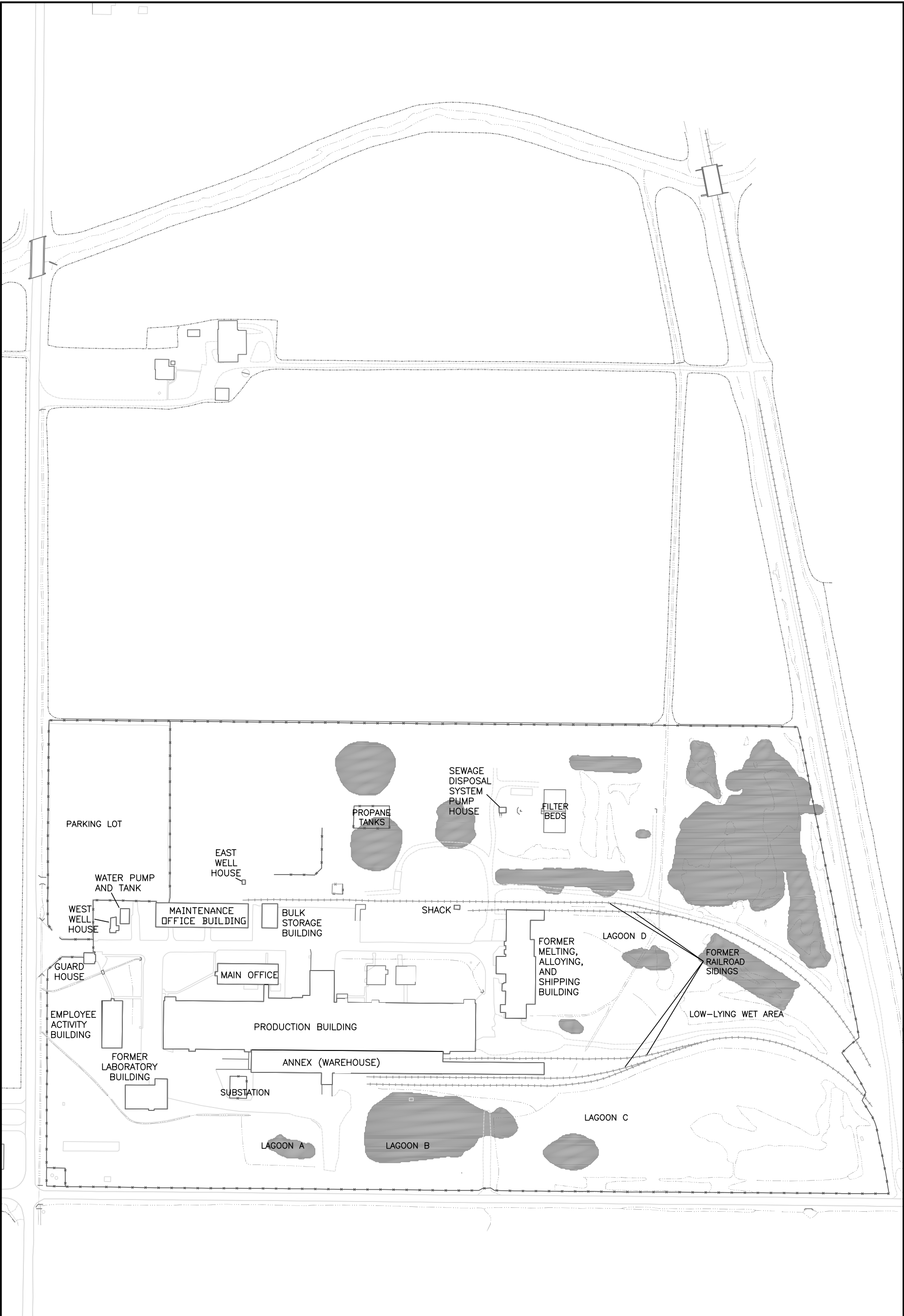
U.S. Army Corps of Engineers
Buffalo District
**LUCKEY SITE
FS REPORT**

Extent of Impacted Soils
Unrestricted Land Use

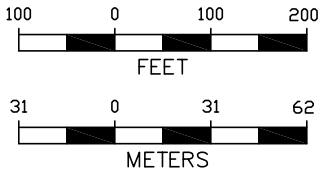
SAIC Science Applications International Corporation Columbus, Ohio

DRAWN	DATE	SCALE	PROJECT NO.	FIGURE NO.
BJW	03-19-01	AS SHOWN	04-1612-503	3.1

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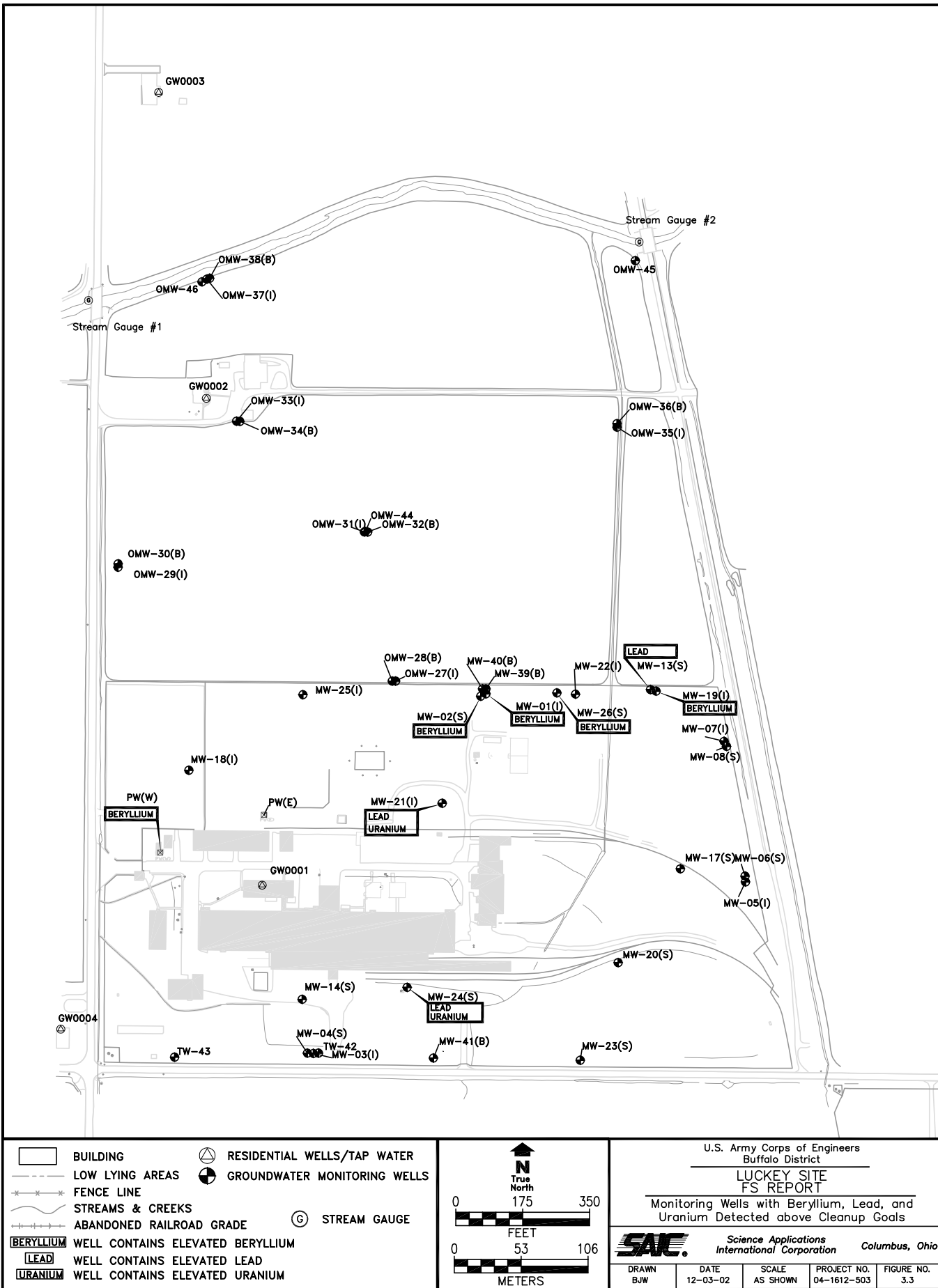


- BUILDING
- LOW-LYING WET AREAS
- FENCE LINE
- STREAMS & CREEKS
- ABANDONED RAILROAD GRADE
- VOLUME ESTIMATE BASED ON ANALYTICAL DATA FROM SOIL BORINGS



U.S. Army Corps of Engineers Buffalo District				
LUCKEY SITE FS REPORT				
Extent of Impacted Soils Industrial Land Use				
		Science Applications International Corporation		Columbus, Ohio
DRAWN BJW	DATE 07-16-02	SCALE AS SHOWN	PROJECT NO. 04-1612-503	FIGURE NO. 3.2

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4.0 TECHNOLOGY TYPES AND PROCESS OPTIONS

This section describes the identification and screening of technology types and process options for the Luckey site. The purpose of the identification and screening is to determine suitable technologies and process options that can be assembled into remedial alternatives capable of mitigating the existing contamination. The EPA *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (EPA 1988) established a structured process for this purpose. A series of steps is used to reduce the universe of potential alternatives to a smaller group of viable ones, from which a final remedy may be selected. These steps include:

- Identifying general classes of response actions, or general response actions (GRAs), suitable for the site (Section 4.1).
- Identifying technologies and process options applicable to the general response actions and performing an initial screening (Section 4.2).
- Performing a detailed evaluation of the screened technologies and process options for effectiveness, implementability, and cost (Section 4.3).

4.1 GENERAL RESPONSE ACTIONS

This section describes the GRAs and remedial technologies that are potentially applicable at the Luckey site. GRAs are actions that will satisfy the RAOs (Section 3) for a specific medium, and may include various process options. GRAs are not remedial alternatives but are potential components of alternatives. Proposed remedial alternatives are presented in Section 5 and include GRAs or combinations of the GRAs presented below. GRAs were selected based on the media of concern (soil and groundwater). The GRAs identified for the Luckey site include no action, land use controls, monitoring, containment, removal, treatment, and disposal. Table 4.1 provides a media-specific summary of the GRAs, remedial technologies, and process options for the Luckey site COCs.

4.1.1 No Action

In this GRA, no action would be taken to reduce any hazard to human health or the environment. This action complies with the CERCLA requirement to provide an appropriate option or component of an alternative if no unacceptable risks are present and to provide a baseline against which other alternatives can be compared.

4.1.2 Land Use Controls and Monitoring

Generally, land use controls (physical, legal, and administrative mechanisms) reduce the potential for exposure to contaminants, but do not reduce contaminant volume or toxicity. These controls are utilized to supplement and affect the engineering component(s) of a remedy (treatment, removal, etc.) during short- and long-term implementation.

The primary goal of land use controls is to restrict the use of, or limit access to, real property using physical, legal, and/or administrative mechanisms to ensure protectiveness of the remedy. Particular land use controls under consideration at the Luckey site include measures that will restrict land use changes over the long-term, such as governmental controls, proprietary controls, and informational devices. Governmental controls could include building restrictions and zoning controls, while proprietary measures could include negative easements. Informational devices can be governmental (i.e., such as handing out information as part of a permit process) or proprietary (i.e., entering a notice on a deed). Land use controls can be used to supplement engineering controls; however, land use controls are not to

be used as the sole remedy at a CERCLA site unless the use of active measures such as treatment and/or containment of source material are determined to not be practicable [(40 CFR § 300.430(a)(1)(iii)(D)].

Physical mechanisms, such as fences, signs, and/or security personnel, bar access to contaminants using physical barriers and would be implemented in conjunction with almost all remedial alternatives to limit access during ongoing remedial activities.

If land use controls are selected as a component of a remedial alternative for the Luckey site, the effectiveness of the remedy must be reviewed every five years. Such reviews are required when limited use or restricted access is part of the alternative. If the site ever achieves a level of contamination that allows for unlimited use and unrestricted release, then, at that time, five-year reviews may be discontinued.

Environmental monitoring would be conducted in conjunction with almost all remedial alternatives to evaluate contaminant concentrations during ongoing remedial actions; to assess the effectiveness of remedial actions; and to ensure that any off-site migration of contaminants is detected thereby enabling mitigation. Environmental monitoring would be tailored to the selected remedial alternative. An adequate monitoring program includes periodic sampling of all media, such as soil, groundwater, surface water, sediment, and air that could be affected by the continued presence of contaminants.

4.1.3 Containment

Containment can effectively reduce contaminant mobility and the potential for exposure. However, containment actions do not reduce contaminant volume or toxicity. When consolidation is used in conjunction with containment, the overall area of contamination is reduced, thereby reducing the area of potential exposure to individuals. The primary containment technology considered for soil at the Luckey site is capping with consolidation. Capping involves covering an area with a low-permeability material (e.g., native soil, clay, concrete, asphalt, synthetic liner, or multi-layered) to reduce infiltration of water and the migration of contaminants.

Containment actions for groundwater include technologies that protect human health and the environment by physically precluding contact with the contamination. Containment technologies for groundwater prevent or alter the natural groundwater flow by constructing a low-permeability material barrier (e.g., sheet piles, geosynthetic membrane, slurry walls, jet grouting, soil freezing, and hydraulic barriers) to reduce the migration of contaminants and the potential for exposure. Since containment would restrict or slow the flow of groundwater from contaminated areas, measures must be taken to control the influx of new groundwater such as the infiltration of surface water. This could be accomplished by surface capping of contaminated areas or by removal of groundwater upgradient of the barrier.

4.1.4 Removal

Removal of contaminated soils would reduce the potential for long-term human and environmental exposure. For example, impacted soil could be excavated and disposed either on site in a designated location or off site in an appropriately licensed disposal facility. Excavation would minimize long-term direct human contact with and the local migration of contaminated material.

Removal of contaminated groundwater would reduce the potential for long-term human exposure. Groundwater could be removed using conventional extraction well technology (e.g., vertical and/or

horizontal wells). Dewatering would minimize direct human contact with contaminated material as well as its migration.

4.1.5 Treatment

The treatment options evaluated for contaminated soil at the Luckey site include various physical, chemical, biological, and thermal technologies. Physical processes involve either physically binding the contaminants to reduce their mobility or the potential for exposure (e.g., encapsulation, thermoplastic solidification, solidification/stabilization, or vitrification) or extracting them from a medium to reduce volumes (e.g., soil washing or soil sorting). Chemical treatment processes add chemicals (in situ or ex situ) to react with contaminants to reduce their toxicity or mobility (e.g., chemical oxidation/reduction, chemical soil washing, hydrolysis, neutralization, or stabilization). Biological treatment involves using microbes to degrade or concentrate contaminants. Thermal treatment such as incineration uses high temperatures to volatilize, decompose, or melt contaminants.

Physical treatment processes considered for groundwater include various in situ and ex situ approaches, such as adsorption, air stripping/packed tower, evaporation ponds, crystallization, and permeable treatment walls. In addition, a passive in situ physical treatment process under consideration for groundwater at the Luckey site is monitored natural attenuation (MNA). Chemical processes include techniques that use chemicals to cause reactions, facilitating the removal of contaminants. These techniques include chemical coagulation/precipitation, catalysis, hydrolysis, or geochemical immobilization. Biological treatment involves using microbes to degrade or adsorb groundwater contaminants. Thermal treatment consists of using elevated temperatures to initiate a phase change (e.g., liquid to gas) to remove contaminants such as liquid/gas phase interface manipulation and oxidation.

4.1.6 Disposal and Handling

Disposal and handling of soils would involve the permanent and final placement of waste materials in a manner that protects human health and the environment. Soil media could be disposed on site, disposed on site in an engineered facility, or off site in a permitted or licensed facility such as a regulated landfill. Similarly, concentrated waste resulting from treatment processes could be disposed either on site in a permanent disposal cell or off site in an approved disposal facility. Transportation could be accomplished using a variety of modes. Truck, railcar, and/or barge transportation could be used to move soils on site or ship waste materials off-site.

Disposal actions for the discharge of water include deep well injection, discharge to surface water, or discharge to a publicly owned treatment works (POTW) or other disposal facility in accordance with required permits. Beneficial reuse (e.g., land spraying/irrigation, reclamation/recycle/reuse) also will be considered for the discharge of groundwater. Transport could be accomplished using various modes of transportation. Truck, railcar, and/or barge transport could be used ship waste materials on site or off site.

4.2 INITIAL SCREENING OF TECHNOLOGIES

This section describes the identification and initial screening of potential technologies to meet the RAOs. Technology types and process options were selected on the basis of their applicability to the environmental media of interest (e.g., soil and groundwater). Process options were either retained or eliminated from further consideration on the basis of technical implementability. The rationale for either retaining or eliminating options is explained below and summarized in Table 4.2 for soils and Table 4.3 for groundwater.

4.2.1 No Action

No action would be taken to implement remedial technologies to reduce any hazard to human health or the environment. This action complies with the CERCLA requirement to provide an appropriate option or component of an alternative if no unacceptable risks are present.

4.2.2 Land Use Controls and Monitoring (Soils and Groundwater)

Actions being considered for the Luckey site include land use controls and environmental monitoring. Land use controls are physical, legal, and administrative mechanisms employed to restrict the use of, or limit access to, real property to prevent or reduce risks to human health and the environment. The implementability of legal and administrative mechanisms depends on an entity assuming responsibility for initiating, implementing, and maintaining the controls. The implementability of legal and administrative controls depends upon arrangements made between property owners in different governmental jurisdictions and the authority of local governments. Specific characteristics of the site determine which controls are appropriate. Legal impediments and costs also affect implementability and schedules. The NCP has outlined criteria to evaluate when the use of land use controls would be acceptable as a component of a remedial alternative. Sites containing residual contamination above acceptable concentrations for unrestricted use require environmental monitoring and five-year reviews to determine if the integrity of the controls remains intact. If the site ever achieves a level of contamination that allows for unlimited use and unrestricted exposure, then at that time five-year reviews may be discontinued.

4.2.2.1 Administrative Mechanisms

Three types of administrative mechanisms can be placed on a property:

- governmental controls (e.g., zoning, local permits, police power ordinances, groundwater use restrictions, condemnation of property)
- enforcement tools (e.g., administrative orders, consent decrees).
- informational devices (e.g., state registry, advisories).

Governmental Controls: Controls using the regulatory authority of a governmental entity to impose restrictions on citizens or sites under its jurisdiction. Generally, state or local governments must establish controls of this type.

Enforcement Tools: Tools, such as administrative orders or consent decrees, available under CERCLA, that can be used to restrict the use of land. Enforcement authority can be used to either 1) prohibit a party from using land in certain ways or from carrying out certain activities at a specified property, or 2) require a settling party to put in place some other form of control, such as a proprietary control.

Informational Devices: Informational tools that provide information or notification that residual or capped contamination may remain on site. Common examples include registries of contaminated properties and advisories.

4.2.2.2 Legal Mechanisms

Proprietary controls (e.g., deed notices, easements, covenants, equitable servitude, reversionary interest, state use restrictions, conservation easements) also can be placed on a property. Proprietary controls are contractual mechanisms, based on private property law, used to restrict or affect the use of

property. These can be implemented without the intervention of any federal, state, or local regulatory authority.

Legal mechanisms could be difficult to implement and maintain from an administrative perspective. The State of Ohio will not impose proprietary controls without the consent of the property owner. Certain land controls, such as a negative easement, may make transfer of the property from one owner to another more difficult. Other land use controls require the involvement of local government to implement, maintain, and enforce the controls. Local government involvement occurs on a voluntary basis. In some cases the federal or state government may acquire a real estate interest in order to restrict land use and control access.

4.2.2.3 Physical Mechanisms

Physical mechanisms include the use of fences, berms, warning signs, and security personnel around a contaminated site to minimize the likelihood or potential for unauthorized access. Signs can be used to identify restricted areas and/or indicate prohibited activities. These measures are designed to reduce the potential for direct human contact with contaminated media. Physical mechanisms are retained for further consideration.

Land use controls (administrative, legal, and physical mechanisms) should be created so that they exist for as long as needed to implement the remedy and are not affected by transfers in land ownership. Recordable and permanent real estate interests, such as easements, are desirable to ensure the enforceability of the land use controls and provide notice to the public and future land owners. The protectiveness of a remedy utilizing land use controls also can be enhanced by layering or employing a system of mutually reinforcing land use controls.

Costs associated with the imposition of such land use controls would be expected to include legal costs to establish the controls. These costs are difficult to project but could be substantial. Elevated costs would be anticipated to adequately account for land use controls to address future management of soils not attaining media-specific cleanup goals.

All land use controls are retained for further consideration.

4.2.2.4 Environmental Monitoring

Environmental monitoring would be tailored to the selected remedial alternative so that monitoring objectives are fulfilled. An adequate monitoring program includes periodic sampling of all media that could be affected by the continued presence of contaminants. Environmental monitoring would be required for any alternative which does not clean the site for unrestricted use. Environmental monitoring includes the following media.

Soil Monitoring: Periodic monitoring of surface and subsurface soils would determine whether contaminants are migrating into undisturbed areas. The degree of monitoring required and the duration of continuing monitoring activities would be determined by the selected remedial action.

Groundwater Monitoring: Groundwater monitoring would consist of radiological and chemical analyses of samples collected from groundwater underlying and surrounding the site. Monitoring would be implemented using upgradient and downgradient wells to assess potential impacts from contaminated soils.

Surface Water Monitoring: Surface water monitoring includes chemical and radiological monitoring of surface waters to determine if dissolved or suspended contamination is present.

Sediment Monitoring: Periodic monitoring of sediments in runoff and Toussaint Creek would determine whether contaminants are being transported to the Creek via surface water runoff. Contaminant concentrations would be monitored downstream in areas of known sediment deposition and quiescent flow conditions and compared with background samples. The degree of monitoring required and the duration of continuing monitoring activities would be determined by the selected remedial action.

Air Monitoring: Short-term air monitoring of un-remediated soil areas would consist of radiation and beryllium surveys to determine if radon, contaminated particulate, or gamma levels are exceeding established limits.

Environmental monitoring is retained for further consideration.

4.2.3 Containment (Soils)

Containment actions prevent or minimize contaminant migration and eliminate exposure pathways. The contaminated medium is neither chemically nor physically changed nor are the volumes of contaminated media reduced. The containment action considered for the Luckey site is capping. Capping can reduce the infiltration of surface water through contaminated media and minimize the release of dust and vapors to the atmosphere. The process options screened included caps constructed of native soil, clay, synthetic liner, multi-layered, asphalt, and concrete.

Native soil can be used in areas of low radioactivity to provide an exposure barrier and, in conjunction with surface controls, reduce migration by wind and water erosion. Clay caps also are potentially applicable. Synthetic liners or multi-layered caps of different media would not be as susceptible to cracking and therefore are potentially applicable. Asphalt and concrete caps are susceptible to cracking if not properly maintained. Existing building slabs and paved surfaces can be effective in reducing direct human contact and wind and water erosion.

Therefore, native soil, clay, synthetic liner, multi-layered, asphalt, and concrete caps are retained for further consideration.

4.2.4 Containment (Groundwater)

Containment technologies for groundwater prevent or alter the natural groundwater flow through the installation of vertical or horizontal barriers, thus preventing the migration of COCs. The technology type considered for the Luckey site is vertical barriers. Vertical barrier walls would be constructed down to a naturally-occurring horizontal barrier (such as a clay zone or bedrock) that significantly retards vertical contaminant migration in the groundwater.

Contaminated groundwater and associated soils underlying the site would be effectively isolated from interaction with uncontaminated groundwater through construction of vertical barriers keyed at the base into relatively impermeable clay or bedrock layers at depth. Process options screened included sheet piles, geosynthetic membranes, slurry walls, jet grouting, soil freezing, and hydraulic barriers. These are susceptible to cracking if not properly maintained. Slurry walls are the most common type of subsurface barrier due to their low cost. These walls are constructed in a vertical trench excavated under a slurry. The slurry acts like a drilling fluid by hydraulically shoring the trench to prevent collapse and forming a filter cake on the trench walls to impede fluid losses into the surrounding ground.

The various containment process options are retained for further consideration.

4.2.5 Removal (Soils)

The process option evaluated for soil removal was bulk soil excavation. The techniques utilized for excavation depend upon the areas and locations to be excavated. Large mechanical excavators would be used for easily accessible areas. Where space is limited, smaller mechanical devices or hand tools may be required. Excavation would require the use of dust and surface runoff controls to ensure the safety of workers and the general public. Runoff controls are especially important for any areas draining to a wetland.

Soil excavation is retained for further consideration.

4.2.6 Removal (Groundwater)

The process options evaluated for removal of groundwater include extraction using vertical and/or horizontal wells. Vertical wells remove groundwater from aquifers or perched water zones. Systems utilizing horizontal wells generally require fewer wells than vertical well-based networks since horizontal wells screens provide greater surface area contact with contaminated soils and groundwater. Horizontal wells may also be installed using directional drilling techniques, allowing wells to be installed underneath buildings and other structures. The implementability of vertical and horizontal wells is dependent on the properties of the aquifer and well construction factors. If the source contamination is not removed, continual groundwater extraction may be required to ensure long-term effectiveness.

Both vertical and horizontal wells are retained for further consideration.

4.2.7 Treatment (Soils)

Process options evaluated for soil treatment include various in situ and ex situ physical, chemical, biological, and thermal options.

4.2.7.1 Physical Treatment

Physical treatment process options evaluated included encapsulation, thermoplastic solidification, stabilization/solidification, vitrification, soil washing, and soil sorting.

Encapsulation: Encapsulation is the ex situ physical sealing of wastes using various cement- and silicate-based mixtures to act as binding agents to minimize the migration of contaminants. The soil contaminants at the Luckey site are not highly mobile primarily due to the clayey soils that tend to bind metals and radionuclides. Encapsulation of large volumes of soil containing clay and silt is difficult due to the fine-grained nature of the soil particles. Encapsulation was eliminated from further consideration due to potential difficulty in implementing this technology.

Thermoplastic Solidification: Thermoplastic solidification seals wastes in an asphalt bitumen, paraffin, or polyethylene matrix. Similar to encapsulation, this ex situ process was eliminated due to potential difficulties in implementation.

Stabilization/solidification: Stabilization/solidification technologies also employ various cement- or silicate-based mixtures to physically bind contaminants in an impervious matrix. The resulting solids resist leaching and minimize migration. The contaminants at the Luckey site are not highly mobile primarily due to the clayey soils, which tend to bind metals and radionuclides. Most solidification

processes result in a significant increase in volume (up to double the original volume). Ex situ and in situ solidification has been used effectively to stabilize soils contaminated with inorganic constituents. This option is retained for further consideration.

Vitrification: Vitrification involves the ex situ or in situ immobilization of COCs in a glasslike matrix. Vitrification has been shown to reduce the dose rate for gamma-emitting radionuclides due to the increase in density of the vitrified matrix. Further, both alpha and beta emitters are sealed in the glass. The ex situ vitrification process involves blending glassmaking constituents with the waste and feeding the mixture into a furnace at high temperatures (1,100°C to 1,400°C). The waste materials are melted in with the molten glass, and upon cooling a solid mass forms that traps the contaminants in the glass matrix. A pretreatment step may be required to reduce the moisture content or reduce the size of the feed material. Small quantities of inorganics may be volatilized during the process, and afterburners may be used to convert partially burned organics in the exhaust to carbon dioxide.

In situ vitrification has been demonstrated at DOE-owned facilities for containment of radionuclides. In the process, electrodes are inserted into an area and electrical resistance is used to heat the material to a molten state. The resulting vitrified mass still contains radionuclides and still presents a risk to users of the site. The site could not be released for unrestricted use after in situ vitrification and would not be usable for the projected future use scenarios.

Ex situ vitrification is retained for further consideration. In situ vitrification is eliminated from further consideration.

Soil Washing: Soil washing is an ex situ process that can achieve volume reduction of contaminated soils and sediments in two ways: by dissolving or suspending the contaminants in the wash solution or by concentrating the contaminants into a smaller volume through particle size separation. Soil washing systems that incorporate both techniques are generally the most effective. Soil washing would involve pre-treating soils to remove larger objects, then washing the soils with water (with or without additives to improve contaminant extraction) to remove target constituents. Conventional soil washing systems are not typically effective for soils containing large amounts of clay and silt, such as the soils at the Luckey site. Incorporating other physical and chemical processes can enhance the effectiveness of soil washing. Technology screening tests at other FUSRAP sites indicate that soil washing combined with chemical extraction could reduce the volume of soils requiring management as radioactive waste.

Following treatment, the smaller contaminated soil fraction could be given an additional soil treatment (such as solidification) and disposed. The “clean” soils from the treatment process could be placed back on site or reused at another site. During operation, the majority of the process water is filtered and recycled back into the treatment system. A small volume of this water stream would require periodic discharge. This option is retained for further consideration.

Soil Sorting: Soil sorting is an ex situ process in which soils are mechanically sorted to separate radiologically contaminated soils from clean soils. This technology does not produce any secondary waste and requires no process additives. Soils containing radioactive particles could be separated using a computer-controlled array of pneumatically actuated gates. The screened soils would move on a conveyor in a controlled layer, under an array of radiation detectors. However, the COCs at the Luckey site are typically contained with the fine-grained clay and silt particles that are not effectively treated by soil sorting. In addition, soil sorting is ineffective for beryllium-contaminated soils. Therefore, soil sorting will be eliminated from further consideration.

4.2.7.2 Chemical Treatment

Chemical process options include a variety of processes, such as chemical oxidation/reduction, chemical soil washing, hydrolysis, in situ neutralization, and stabilization.

Chemical oxidation/reduction: Chemical oxidation/reduction involves the addition of appropriate chemicals to raise or lower the oxidation state of the reactant. Potentially large amounts of chemical waste products would be generated through the use of this option, requiring additional waste treatment and disposal.

Chemical soil washing: Chemical soil washing processes are similar to physical soil washing methods, with the exception that chemicals are used as treatment fluids. This option would produce an additional waste stream that may be difficult to treat.

Hydrolysis: Hydrolysis involves the reaction of an organic chemical with water or hydroxide ions to break down the chemical into a similar, less toxic form. This process is not applicable to the COCs identified at the Luckey site.

Neutralization: Neutralization is an in situ process in which chemicals are injected into the impacted soil strata or groundwater to affect a pH adjustment. This process is not applicable for the COCs identified at the Luckey site.

Stabilization: Stabilization utilizes various chemicals to bind waste in a form that resists leaching. This process is not applicable to the COCs identified at the Luckey site.

For metal and radioactive contaminants, these processes involve adding chemicals to reduce or remove the mobility or toxicity of the constituents in the soil. The potential exists for generating large volumes of hazardous waste and by-products, which would require additional treatment. Chemical processes for soil treatment are not retained for further consideration.

4.2.7.3 Biological Treatment

Bioremediation technologies involve destruction or transformation techniques in which a favorable environment is created for microorganisms to grow and use the contaminants as a food or energy source. Processes include slurry-phase, solid phase, and anaerobic biodegradation. Biological treatment is generally most effective for treating organic contaminants. Bioremediation is generally not applicable for the treatment of inorganic contaminants. This option was eliminated from further consideration.

4.2.7.4 Thermal Treatment

Thermal treatment uses high temperatures to volatilize, decompose, or melt the contaminants. There are various forms of thermal treatment technology including incineration, infrared, retorting, pyrolysis, and low temperature thermal desorption. Thermal treatment processes are generally used for the destruction of organic compounds and would not be effective for treating inorganic compounds. Thus, thermal treatment was eliminated from further consideration.

4.2.8 Treatment (Groundwater)

Process options screened for the treatment of groundwater consist of ex situ and in situ processes, including various physical, chemical, biological, and thermal options. These treatments also can be used for treating surface water and discharges from soil dewatering.

4.2.8.1 Physical Treatment

Physical process options evaluated included ex situ treatment options (adsorption, air stripping/packed tower, evaporation ponds, crystallization, flocculation/precipitation, physical catalysis, chelation, dissolved air flotation, ultra/micro/nanofiltration, reverse osmosis, ion exchange, sedimentation) and in situ measures (permeable treatment walls, liquid gas extraction, vacuum extraction, air sparging, electro kinetics, and MNA).

Ex situ Process Options

Adsorption: Adsorption processes involve the displacement of contaminants from one medium to another. Some inorganics have shown good to excellent adsorption potential using activated carbon, alumina, or other media developed for water and wastewater treatment. Spent adsorption media may be regenerated and reused until efficiency declines to a predetermined level. This treatment option is potentially applicable and is retained for further consideration.

Air Stripping/Packed Tower: Air stripping involves the addition of large volumes of air to the fluid to be treated. Air stripping is most frequently used for removal of volatile organics and radon gas and is not applicable to groundwater COCs at the Luckey site. Air stripping was eliminated from further consideration.

Evaporation Ponds: Evaporation ponds involve the evaporation of water and consequent concentration of organic and inorganic wastes. The process is dependent upon climatic conditions and is not practical in non-arid and cold regions. Evaporation ponds were eliminated from further consideration.

Crystallization: In crystallization, solutes are crystallized from a saturated solution when the solvent is cooled, or water is separated from solution by cooling it until ice crystals form. The process is energy intensive, decreasingly effective with less saturated solutions, and not applicable for the COCs identified at the Luckey site. Crystallization was eliminated from further consideration.

Flocculation/Precipitation: Several different precipitants have been shown to effectively remove metals and radionuclides from groundwater. Flocculation is a physical process that agglomerates particles that are too small for gravitational settling. Flocculation results from aggregation due to the random thermal motion of fluid molecules and by velocity gradients in the fluid. This process option is potentially applicable for metals and radionuclides and is retained for further consideration.

Physical Catalysis: The use of a suitable physical catalyst process allows a substance to be dehalogenated or otherwise reacted from one phase to another. Physical catalysis is generally not feasible for metals and was eliminated from further consideration.

Dissolved Air Flotation: In dissolved air flotation, air is injected while the wastewater is under pressure. Fine bubbles are released and attach to suspended solids, reducing their specific gravity and aiding their rise to the surface. This technology is not applicable to dissolved metals or radionuclides and was eliminated from further consideration.

Ultra/Micro/Nano-filtration: These filtration techniques use pressure and a semi-permeable membrane to separate nonionic materials from a solvent. This is generally used for suspended solids, oil and grease, large organic molecules, and complex heavy metals. This technology is not applicable to COCs in groundwater at the Luckey site and was eliminated from further consideration.

Reverse Osmosis: In reverse osmosis, pressure is applied to the solution to force the solvent flow from the more dilute to the more concentrated solution. The membrane through which the solvent flows is impermeable to the dissolved ions. This process is typically used to separate water from inorganic ions. This is potentially applicable and is retained for further consideration.

Ion Exchange: Ion exchange has been widely used for the treatment of inorganic wastes. Ion exchange is effective in treating dilute concentrations of contaminants. Exchangers can be produced to remove low concentrations of toxic metals from a wastewater containing a high background concentration of other non-toxic contaminants. This treatment option is retained for further consideration.

Sedimentation: Sedimentation is a post-treatment step that will be retained for possible use in conjunction with flocculation/precipitation.

In situ Process Options

Permeable Treatment Walls: In this process, treatment walls are emplaced to intercept groundwater. As the impacted water flows through the wall, the contaminants are decomposed or bound as a result of chemical reactions. This option is adaptable to a variety of sites when used in conjunction with funnel and gate systems. Depth of the contaminated groundwater is a major constraint on applicability. This technology is best applied where there is a well-characterized contamination plume and flow gradient. This option is eliminated from further consideration because of the localized and disconnected distribution of COCs in groundwater and the potential impacts on the flow gradient as a result of variable operation of the on-site production well.

Liquid Gas Extraction: Various gases are used to alter the properties of solvents to make extraction of organics more rapid and efficient. This option is not applicable for metals and was eliminated from further consideration.

Vacuum Extraction: This process option involves the use of vacuum pumps to remove contaminants from groundwater. It is used for volatile organics, not metals, and was eliminated from further consideration.

Air Sparging: Air is introduced to groundwater using horizontal wells to volatilize organic contaminants. This option is not used for metals and was eliminated from further consideration.

Chelation: Chelating molecules exhibit a high degree of selectivity for many metals. Chelating agents are used to enhance the in situ solubility or mobility of target constituents. This option is retained for further consideration.

Electrokinetics: Electrokinetics is an electrochemical process involving electrodes and permeable membranes in which cations (such as metals and hydronium ions) are driven through the saturated zone (or interstitial moisture above the water table) to one or more anodes, while anions are forced to the cathode(s). At the anode, metal contaminants cross a semi-permeable membrane and are extracted on the surface for treatment or disposal. Because of its potential for moving and removing metal contaminants from the groundwater, this option has been retained for further consideration.

Monitored Natural Attenuation: MNA is a passive remedial measure that relies on natural processes to reduce the contaminant concentration over time. MNA is a viable remedial process option if it can reduce contamination within a reasonable time frame, given the particular circumstances of the site, and if it can result in the achievement of remediation objectives. Use of MNA as a component of a remedial alternative is appropriate along with the use of other measures, such as source control or containment measures. MNA has been retained for further consideration.

4.2.8.2 Chemical Treatment

Chemical treatment processes include ex situ and in situ techniques, which use chemicals to cause reactions to facilitate the removal of the contaminants from groundwater. Several chemical process options were evaluated including coagulation/precipitation, chemical hydrolysis, chemical catalysis, and geochemical immobilization.

Coagulation/Precipitation: This process can be performed both ex situ and in situ. Several different precipitants have been shown to effectively remove metals and radionuclides from groundwater. In coagulation, particles that are too small for gravitational settling are agglomerated as a result of adding chemicals. Optimum coagulation treatment is achieved with precise control of pH, turbidity, chemical composition of water, mixing temperature, and other factors. This process option is potentially applicable for metals and radionuclides and is retained for further consideration.

Chemical Catalysis: Chemical catalysis can be conducted ex situ or in situ and involves the addition of a substance that permits the transfer of a contaminant from one phase to another, or accelerates a chemical change of the contaminant. The substance added is not permanently affected by the reaction. Chemical catalysis is retained for further consideration.

Chemical Hydrolysis: This is in situ chemical process of decomposition involving the splitting of a bond and reaction with the hydrogen and /or hydroxyl ions of water. Chemical hydrolysis is not applicable to COCs in groundwater at the Luckey site and was eliminated from further consideration.

Geochemical Immobilization: Geochemical immobilization is an in situ process that involves locally adjusting the pH and reduction-oxidation (redox) conditions. This reduces the solubility and/or changes the speciation of contaminants, largely precipitating them in the saturated zone. This alternative has been retained for further consideration.

4.2.8.3 Biological Treatment

Biological treatment involves using microbes in situ to degrade or adsorb groundwater contaminants.

Bioremediation: Bioremediation technologies are destruction or transformation techniques directed towards stimulating microorganism growth and their consumption of the contaminants as a food or energy source. Bioremediation has been successfully used for some heavy metals and is retained for further consideration.

Biological Sorption: In biological sorption, various active and inactive microorganisms, such as algae and fungi, that are capable of adsorbing metallic ions are used to remove heavy metals from aqueous solutions. The process takes advantage of the natural affinity for heavy metal ions exhibited by algae cell structures. When the adsorptive capacity of the microorganisms is reached, the metals can be removed and concentrated for subsequent recovery. This option is retained for further consideration.

4.2.8.4 Thermal Treatment

Thermal treatment uses temperature elevation to initiate a phase change (e.g., liquid to gas) to remove contaminants from groundwater. Thermal processes, such as incineration and distillation, steam stripping, evaporation, super critical water oxidation, and wet air oxidation are generally used to destroy organic compounds and would not be effective in treating the groundwater contaminants at the Luckey site. Therefore, thermal treatment options were eliminated from further consideration.

4.2.9 Disposal and Handling (Soils)

Both on-site and off-site disposal options were considered for the disposal of contaminated soils.

4.2.9.1 On-site Disposal

On-site disposal of soils in an engineered structure has been retained for further consideration. Land encapsulation is a proven and well-demonstrated technology. A disposal facility, similar to the one constructed at Canonsburg, Pennsylvania for the Uranium Mill Tailings Remedial Action Program (UMTRAP), is considered protective of public health with erosion-proof barriers designed to ensure long-term control of radionuclides (Camp, Dresser & McKee 1985). Such a facility would be designed and constructed to contain all the excavated materials or residuals after treatment. Limited land space is available on the site for a disposal facility. Nonetheless, an on-site, engineered structure has been determined to be potentially applicable. This process option is retained for further consideration.

4.2.9.2 Off-site Disposal

Among the off-site disposal options considered were a new facility at a location in Ohio, or an existing federal or commercially licensed facility. A new off-site disposal facility in Ohio could be designed to reduce potential exposure and minimize the migration of contaminated material. A disposal facility, similar to the UMTRAP design referenced above, is considered protective of public health. This option could be considered if land is made available or treatment significantly reduces volume. Therefore, a newly constructed off-site disposal facility has been determined to be potentially applicable and is retained for further consideration.

Existing federal or commercially licensed or permitted disposal facilities exist for the types of waste at the Luckey site and are retained for further consideration. Specific off-site disposal facilities are identified and evaluated in Appendix 4A.

4.2.9.3 Handling

Off-site disposal requires waste materials to be transported to the selected disposal facility. A number of transportation options exist. The transportation options considered include trucks, railcars, and barges. These modes of transportation could be used individually or in combination to haul waste materials from the Luckey site to the disposal facility. The scenarios for transportation could include trucking to a rail loading facility, direct trucking to the disposal facility, or trucking to a barge loading facility. Direct loading to a railcar is feasible only if a rail spur can be constructed on the site. Conveyance equipment could be fitted with a cover and/or liner. Truck, rail, and barge options have been used successfully for the types of waste that will be generated at the Luckey site and will be retained for further consideration.

4.2.10 Disposal and Handling (Groundwater)

On-site and off-site disposal and discharge options, as well as beneficial reuse, were considered for groundwater. The process options screened included: discharge to surface water, deep well injection, disposal to a POTW or other disposal facility, land spraying/irrigation, and reclamation/recycle/reuse.

4.2.10.1 On-site Disposal/Discharge

Discharge to surface water and deep well injection were screened. Discharge to surface water could be used as a post-treatment step for treated water and thus the treated water would not need to be transported off site. Under CERCLA, an NPDES permit is not required for discharge to surface waters; however, the substantive requirements of a permit must be met. Deep well injection involves the injection of either treated or untreated water into an isolated underground zone. This option may be subject to meeting the substantive requirements of permitting. Both options are viable for the Luckey site and are retained for further consideration.

4.2.10.2 Off-site Disposal/Discharge

Among the off-site disposal/discharge options are the use of existing POTWs or other commercial wastewater disposal facilities. Under this option, either treated or untreated water could be sent to these facilities, provided it is in compliance with the facility's permits and waste acceptance criteria. This option is retained for further consideration.

4.2.10.3 Handling

Off-site disposal requires that waste materials to be transported to the selected disposal facility. A number of transportation options exist. The transportation options considered include trucks, railcars, and barges. These modes of transportation could be used individually or in combination to transport wastewater from the Luckey site to the disposal facility. The scenarios for transportation could include trucking to a rail loading facility, direct trucking to the disposal facility, and trucking to a barge loading facility. Truck, rail, and barge options have been used successfully for the types of waste that will be generated at the Luckey site and will be retained for further consideration.

4.2.10.4 Beneficial Reuse

One alternative for disposing or discharging contaminated groundwater is recycling or reuse in activities that would limit the potential for human exposure to acceptable concentrations. One reuse option considered was land spraying/irrigation. This is typically used for organic wastes and is not applicable to COCs in groundwater at the Luckey site. Reclaiming or recycling also were considered, but because the COCs are not in sufficient concentrations to use as a commercial product this option was not retained.

4.3 DETAILED SCREENING OF TECHNOLOGIES

The remedial action technologies that passed the initial screening in the previous section are now further evaluated using the criteria of effectiveness, implementability, and cost, (three of the NCP balancing criteria). The rationale for either retaining or eliminating options at this stage is explained below and summarized in Table 4.4 for soils and Table 4.5 for groundwater.

4.3.1 Criteria Used for Detailed Screening

4.3.1.1 Effectiveness

The criterion of effectiveness assesses the ability of the technology to protect human health and the environment by reducing the toxicity, mobility, or volume of contaminants. The ability of the technology to meet the RAOs was evaluated. The time required to achieve the RAOs also was considered, including the potential length of exposure to the public. Short-term protection involves reducing existing risks to workers and the community during implementation of remedial actions. This criterion also includes long-term protectiveness and addresses the magnitude of residual risks and long-term reliability. In view of the 1,000 year timeframe for some response actions, the fading of institutional memory must be included in the evaluation of long-term protectiveness and reliability. In general, the following proposed technologies have not been tested for 1,000 year effectiveness and implementability.

4.3.1.2 Implementability

Each technology was evaluated in terms of implementability including: technical feasibility, administrative feasibility, and availability of the necessary materials, equipment, and work force. The assessment of short-term technical feasibility considered the ability to construct the given technology and its short-term reliability. Long-term technical feasibility considers the ease of undertaking additional remedial actions if necessary, monitoring the effectiveness of the remedy, and operation and maintenance (O&M). Administrative feasibility was evaluated by reviewing the ability to obtain the necessary approvals, the need to coordinate with other agencies, and the likelihood of obtaining a favorable community response.

4.3.1.3 Cost

The cost criterion includes capital costs and O&M costs. O&M costs are estimated for a 30- to 1,000-year period depending on the presence and type of hazardous substances, pollutants, or contaminants that may pose a threat to human health or the environment remaining at the site. Costs for each technology are rated qualitatively, on the basis of engineering judgment, as high, moderate, or low in comparison to the costs of alternative technologies.

4.3.2 No Action

The no action alternative provides a baseline for comparison with all other alternatives and is required by CERCLA. This alternative provides no additional protection for human health and the environment. No remedial actions would be taken to reduce, contain, or remove contaminated soils and no effort would be made to prevent or minimize human and environmental exposure to residual contaminants. Off-site migration of contaminants would not be mitigated under this alternative.

Potential effects on human health and the environment under this alternative are evaluated in the RI (USACE 2000a). The RI showed that the human health risks for current use (i.e., industrial workers) at the Luckey site are within the acceptable cancer risk range of 10^{-6} to 10^{-4} and the non-cancer HI is less than the threshold of 1.0. Lead doses however, exceed target criteria for industrial workers in exposure unit 2. However, future uses could include residential land use and estimated cancer and non-cancer risks exceed acceptable levels under these scenarios. Under the no action alternative, there would be no reduction in the mobility, volume, or toxicity of site-related contaminants.

4.3.3 Land Use Controls and Monitoring (Soils and Groundwater)

The selection of a remedy that does not result in a condition where the property can be released for unrestricted use requires limited action options. Such options include land use controls and environmental monitoring. These options are generally not used as the sole remedy, but are integrated into an alternative that does not achieve unrestricted release. Land use controls and monitoring generally supplement the implementation of an engineering remedy. The protectiveness of a remedy utilizing land use controls also can be enhanced by layering or by employing a system of mutually reinforcing land use controls.

Effectiveness: Land use controls are physical, legal and administrative mechanisms designed to maintain the elements of a remedy and to ensure its protectiveness. Land use controls would increase the protection of human health and the environment over baseline (i.e., no action) conditions by restricting or limiting use of the site. Government or proprietary controls should be more effective over a longer period of time than information devices, as these can be established in perpetuity and are enforceable. Physical mechanisms are used to prevent or limit access to contaminated areas and include a variety of physical barriers and security. The impacted soils at the Luckey site are currently fenced with signs and other security measures, which provide some measure of access control. Environmental monitoring ensures that site conditions do not change without the owners being aware of the changes.

Although there would be no reduction in volume, toxicity, or mobility of contaminants in the soil or groundwater, future risk could be maintained at acceptable levels as a result of these restrictions. To accomplish this, durable land use controls would have to be implemented, maintained, and enforced. Maintaining land use controls throughout a 1,000 year period could present a problem. Maintaining physical mechanisms over a 1,000 year time frame also is uncertain. Environmental monitoring should continue as long as the land use controls remain in effect to ensure appropriate controls continue to be implemented and maintained.

Implementability: Land use controls may be difficult to implement from an administrative perspective. The federal government lacks the authority to implement many effective land use controls. Other land use controls require involvement of the local government to implement, maintain, and enforce. Local government involvement occurs on a voluntary basis. Land use restrictions secured from local governments could limit or bar future site development or use by re-zoning the property. Certain land use controls, such as a negative easement, may make transfer of the property from one owner to another more difficult. Although land use controls may be difficult to implement, in some cases, the federal or state government may acquire a real estate interest in order to restrict land use and control access.

Physical mechanisms are currently in place for on-site soils and groundwater and limited environmental monitoring also is being performed. These process options would be easy to implement.

Cost: The costs for implementing land use controls include low to high capital costs and low O&M costs. Potential legal fees, compensation for implementing land use controls, administrative fees, and possible property purchases could increase the costs of this alternative. The lower bounding cost would include only legal fees; the upper bounding cost would be the purchase of a real estate interest, e.g., a negative easement. Capital cost would be low but O&M costs could be significant. Environmental monitoring would include periodic sampling and is considered to be low capital and low O&M costs.

Land use controls and monitoring are retained.

4.3.4 Containment (Soils)

Containment technologies protect human health and the environment by physically separating the contaminated materials from any potential receptors. The containment process option for detailed screening is an engineered cap. A native soil, clay, asphalt, concrete, synthetic liner, or multi-layer cap could be utilized at the Luckey site. The cap would reduce the potential for human exposure to the underlying contaminated materials and reduce the migration of contaminants into surface water and groundwater. It could also reduce the potential for generation of fugitive dust.

Effectiveness: An engineered cap is a proven effective technology that provides a physical barrier between receptors and contaminated soils. The cap, with regular maintenance, would eliminate the potential for direct contact (absorption, ingestion, or inhalation) and minimize potential exposure to external gamma radiation and radon gas. It also would minimize water infiltration and reduce the mobilization of contaminants leaching from soil to groundwater.

Implementability: No technical problems are anticipated that would limit the implementability of this technology. However, local stakeholders, including government officials, may oppose on-site capping. In addition, capping would require perpetual maintenance. Some clearing and grubbing, rerouting of utilities, and other site preparation would be required before the cap could be constructed. Contaminated soils may need to be amended (i.e. materials added to increase the strength of soils) to reduce future subsidence. Site monitoring would be required for as long as the media under the cap present a potential threat to human health or the environment. This alternative could be difficult to implement administratively because, while a permit is not required, the substantive requirements of a permit must be met as required under CERCLA. The State of Ohio does not allow disposal of radioactive wastes within the State. The long term maintenance and site monitoring requirements could be difficult to maintain because of the need for information to be passed down through generations.

Cost: Capping would consist of low to moderate capital and O&M costs. Capital costs would be higher than land use controls, but lower than excavation and disposal. Capital costs include soil excavation, transportation, and installation of a cap. O&M costs would be a function of the degree of activity needed to address soil subsidence and long-term monitoring requirements.

An engineered cap is retained.

4.3.5 Containment (Groundwater)

Containment technologies protect human health and the environment by physically separating the contaminated materials from potential receptors. For groundwater, this means that the contaminated groundwater would be prevented from migrating to areas where it would be extracted for use.

Effectiveness: Vertical barriers can be effective for groundwater in the short term, but not in the long term due to potential degradation of the seal around the area of contamination. In addition, an effective seal would be difficult to implement around the contaminated groundwater at the Luckey site because of the presence of relatively shallow fractured bedrock. There is not a well defined plume at the Luckey site which would make designing an effective containment option difficult. Horizontal barriers are more difficult to install and are more prone to poor seals than are vertical barriers. Due to shallow bedrock at the Luckey site, planning and installation would be very difficult and costly. Due to these difficulties and potential lack of long-term effectiveness, the vertical and horizontal barrier options were eliminated from further consideration.

Implementability: Vertical barrier implementability varies from easy to moderate depending on the type of barrier used. Horizontal barriers are difficult to implement.

Cost: Capital costs related to vertical and horizontal barriers are moderate to high depending on the size of the area needing containment.

Due to design/installation difficulties and potential lack of ineffectiveness, vertical and horizontal barriers are eliminated from further consideration.

4.3.6 Removal (Soils)

Removal technologies protect human health and the environment by physically separating the contaminated materials from potential receptors. The removal process option retained for detailed screening is soil excavation.

Effectiveness: Soil removal increases protection of human health and the environment over the previously outlined technologies, reducing future residual risk. Exposure to fugitive dust, radon gas, external gamma radiation, contaminants leaching into groundwater, and contaminated surface water runoff would be greatly reduced.

Implementability: Soil excavation uses readily available resources and conventional earth-moving equipment. Some ancillary construction of temporary roads, a staging area for loading and unloading, soil erosion control, excavation dewatering, water treatment, dust control, and additional clearing and grubbing may be necessary. Administrative coordination between remediation activities and the current tenant's operations would need to be well planned to minimize reduced productivity.

Cost: Capital costs related to soil removal are moderate to high. O&M costs would be low.

Soil removal is retained.

4.3.7 Removal (Groundwater)

Effectiveness: Vertical wells are an effective option, but only for the short-term if the option is not accompanied by source removal. Vertical wells are retained as a potential option for use in conjunction with source removal.

Horizontal wells are effective for large areas of contamination where there is a well-defined plume. The groundwater contamination at the Luckey site does not meet these characteristics. Contamination is found in only three or four scattered wells, making it difficult for horizontal wells to be effective. Therefore, horizontal wells were eliminated from further consideration.

Implementability: Vertical wells are easily implementable and resources are widely available commercially for installation. Horizontal wells would be hard to implement because of the lack of a well-defined plume. This would lead to difficulties in correct placement of wells to achieve complete extraction.

Cost: Costs are low for both vertical and horizontal wells.

Groundwater removal using vertical wells is retained.

4.3.8 Physical Treatment (Soils)

Site-specific laboratory or pilot scale data are not available at this time to assess the potential effectiveness of the physical treatment technologies. Published literature, previous experience at other FUSRAP sites, and vendor information was used to judge effectiveness, implementability, and cost.

4.3.8.1 Stabilization/Solidification

Effectiveness: Ex situ immobilization is one of the oldest remediation technologies. It has been successfully used on radioactive and mixed waste to reduce the mobility of contaminants. Treatment of soils and sediments by solidification would pose minimal risks to the local community and workers. Some dust may be generated during excavation; however, the amount generated would be equivalent to that generated with any alternative requiring excavation and soil handling. Most solidification processes result in a significant increase in volume (up to double the original volume) and are typically most effective at treating mixed waste to meet disposal facility acceptance criteria. This process reduces mobility of contaminants but does not reduce the radioactivity of the waste, resulting in a significant increase in volume of mixed waste. This will further increase costs, including transportation and disposal costs.

Implementability: Soils would require excavation and transport to a central staging area for on-site treatment. The solidified materials would be greater in volume than the original waste material. The immobilized waste would then be manifested and sent off site by a licensed transporter for disposal at a licensed disposal facility. Qualified vendors and equipment are readily available to perform this treatment operation.

Cost: Capital costs would be moderate to high. The disposal costs would be significantly increased with this treatment alternative due to the increased volume of waste requiring disposal.

Due to the potential for significant increased volume and thus increased costs associated with disposal, solidification was eliminated from further consideration.

4.3.8.2 Vitrification

Effectiveness: Vitrification is effective at immobilizing contaminants in order to minimize migration. Vitrification is typically used to address highly concentrated mobile contaminants, unlike those at the Luckey site. It also has been used to address radionuclides and is considered effective for highly radioactive wastes. This process, however, has not been tested for beryllium and therefore, its effectiveness is unknown. Vitrification poses a much higher risk to on-site workers compared to other treatment operations due to the high temperatures and specialized equipment used. Beryllium is a metal with a very high melting point. Therefore, given the lack of information on using vitrification with beryllium, the process could require higher temperatures to operate, further increasing the risk to on-site workers. Verifying that all of the contaminated soils have been successfully vitrified can be difficult, since the resulting glass matrix acts as a barrier to sampling not only at the glass matrix-soil interface, but also within the glass matrix itself.

Implementability: Vitrification has been successfully used to treat radioactive contaminants on other projects, but generally for much higher concentrations of contaminants and smaller quantities of wastes. While some volume reduction occurs during melting, the total volume of the final waste material often increases due to the addition of glass formers. Qualified vendors and equipment are readily available to perform this treatment operation.

Cost: Costs for this technology are high.

Vitrification is unproven for beryllium and thus was eliminated from further consideration.

4.3.8.3 Soil Washing

Effectiveness: Soil washing, in combination with chemical extraction, has been proven effective at other FUSRAP sites. Laboratory and conceptual design studies would need to be conducted on soils from the Luckey site to assess treatment processes. A soil washing system would be located on site. Clean soils from the treatment operation could be placed back on site. The contaminated stream would be sent off site for disposal. Much of the water used would be recycled back into the system. A disposal alternative will be required for any wastewater removed from the system during operation and for the balance of the wastewater at the completion of the process.

Implementability: A soil washing system could be located on site where soils could be moved from any place on site for processing. Qualified vendors and equipment are readily available. Approval will be required from regulatory agencies to discharge any water generated.

Cost: Costs are moderate to high, assuming that the treatment is conducted on site and the cleaned soil can be placed back onto the site as backfill.

Soil washing is retained.

4.3.9 Physical Treatment (Groundwater)

The limited volume of contaminated groundwater does not justify the difficulty and cost associated with a train of complicated process options, each designed to treat a single contaminant. Therefore, process options that could not treat uranium and lead, or beryllium were eliminated from further consideration. Process options requiring extensive pilot studies to determine effectiveness also were eliminated from further consideration. Many technologies were eliminated because they have not been previously tested, particularly for beryllium, when there are existing proven processes. Excluded ex situ treatment process options consisted of flocculation/precipitation, coagulation/precipitation, and chemical catalysis. These options were eliminated because their effectiveness for beryllium is unknown and would require extensive pilot studies. In situ options eliminated from further consideration consisted of coagulation/precipitation, bio-remediation, biological sorption, and chemical catalysis. These options also were eliminated because their effectiveness for beryllium is unknown and would require extensive pilot studies. The process options presented below passed these generic screens and are discussed in some detail.

4.3.9.1 Ex situ Process Options

Adsorption

Effectiveness: Adsorption of contaminants in groundwater onto solid phase materials is technically feasible and effective for uranium, beryllium, and lead. Lead and uranium may be adsorbed onto the surfaces of granulated activated carbon, and beryllium may be adsorbed onto the surfaces of activated alumina. A solid waste stream is generated, but results in an overall volume reduction. This reduction is potentially offset by the extra cost to dispose of the solid waste stream.

Implementability: Adsorption is easily implemented and only the media need be changed to address different contaminants. Disposal of the contaminated media is similar to the disposal of contaminated soil. Extraction wells are a common and available technology.

Cost: Costs associated with adsorption are moderate.

This process option is retained.

Reverse osmosis

Effectiveness: Reverse osmosis is a general process for removing metals and other contaminants. It has been used for removal of uranium, beryllium, and lead. Its efficiency for beryllium at low temperatures is 25%. This would result in 75% of the water entering the system being a waste. Treatability studies would need to be performed to determine if the efficiency could be improved with changes in temperature, pH, etc.

Implementability: Reverse osmosis is easily implemented, although retention time, fouling, and degradation may be issues of concern. Standard well drilling processes complete the technology.

Cost: Costs associated with reverse osmosis are moderate to high depending on the type of membrane necessary to remove the specific contaminants and the efficiency of the process.

Because of its low efficiency with beryllium and the need for further study, reverse osmosis was eliminated from further consideration.

Ion exchange

Effectiveness: Ion exchange is an effective process option for removing dilute concentrations of toxic metals and other inorganics from wastewater. The resins may be regenerated and reused.

Implementability: Ion exchange is easily implemented.

Cost: Costs associated with ion exchange are moderate to high depending on the type of resin necessary to remove the specific contaminants

Ion exchange is retained.

Sedimentation

Effectiveness: Sedimentation is often used as a post-treatment step in combination with other physical or chemical treatment options that promote precipitation.

Implementability: Sedimentation is easily implemented, although the processes may require the use of hazardous chemicals and construction of extensive sedimentation basins.

Cost: Costs for sedimentation are considered low to moderate.

Since no precipitation treatment options were retained, sedimentation was eliminated from further consideration.

4.3.9.2 In Situ Process Options

Chelation

Effectiveness: Chelation is an in situ treatment technology used to enhance the in situ solubility or mobility of target constituents and to keep target metal species suspended in solution and amenable to withdrawal from contaminated media. The chelating agents would result in preferential removal of targeted metal species and therefore, minimize the influence of other metal species in the flow system. Chelation is effective for uranium and lead but unproven for beryllium.

Implementability: Standard well drilling processes would be combined with hydrofracturing of soils around the wells to inject chelating agents.

Cost: Costs associated with chelation are considered moderate to high.

Chelation is retained.

Electrokinetics

Effectiveness: Electrokinetics is an in situ treatment technology used at several sites to drive metals contaminants through moist or saturated soils to an electrode where they are collected and removed from the subsurface. It is one of the few technologies that can remove metal contaminants from soils and groundwater as opposed to immobilizing them. Electrokinetics has not been proven effective for beryllium; however, the process is well suited to site-specific conditions (i.e. metals in moist clays) and is anticipated to be adaptable for effectively addressing beryllium.

Implementability: Although electrokinetics has been implemented at comparatively few sites, the equipment and materials are proven and readily available. The electrode technology is comparable to that used in the chlor-alkali industry and the membranes are comparable to those used in reverse osmosis applications. Standard well drilling and power generation processes complete the technology.

Cost: Costs associated with electrokinetics are considered moderate, although a requirement to minimize treatment time can drive costs higher, as more electrodes and power are necessary to achieve shorter treatment times.

Electrokinetics is retained.

Monitored Natural Attenuation

Effectiveness: MNA would reduce contaminant concentrations below target cleanup goals at the Luckey site. The timeframe for reduction varies as a result of lithology and contaminant characteristics.

Implementability: MNA requires extensive site characterization and monitoring until concentrations in groundwater reach target levels, but can be readily implemented.

Cost: Costs associated with MNA are lower than costs associated with most active remediation measures.

MNA is retained.

Geochemical Immobilization

Effectiveness: Geochemical immobilization is an in situ technology that stabilizes metal contaminants without creating a solidified monolith. Although it does not remove metal contamination, geochemical processes are effective in transforming metal speciation and/or limiting the solubility of metals so that dissolved concentrations are less than concentrations of regulatory concern. One side effect of geochemical immobilization may be that, while immobilizing the target compound, other metals may be mobilized.

Implementability: Standard well drilling processes would be combined with hydrofracturing of the soils around the wells to inject the reagents.

Cost: Costs for in situ geochemical immobilization are considered low.

Geochemical immobilization is retained.

4.3.10 Disposal and Handling (Soils)

Disposal technologies protect human health and the environment by physically separating the contaminated materials from potential receptors.

4.3.10.1 Off-site Disposal at an Existing Facility

Effectiveness: The USACE has reviewed disposal practices used on previous cleanups and has contracts with licensed or permitted disposal facilities that can accept radiologically contaminated soil excavated from the Luckey site. Disposal of soil that does not have radiological contamination is not as difficult. Many licensed or permitted facilities can accept the non-radioactive waste stream and are very effective at isolating the material so as to prevent its impacting human health or the environment. By removing, but not treating contaminated soil, no reduction in toxicity, mobility, or volume is achieved. Future risk is reduced only by removing this soil from the Luckey site. However, toxicity and mobility concerns are transferred to the off-site disposal facility. Excavation actually results in an increase in volume. Off-site disposal options would be effective in terms of containing wastes generated by the Luckey site remediation and separating contaminated materials from potential receptors.

Implementability: Disposal of radiologically contaminated waste at an existing facility could be readily implemented based on existing USACE disposal contracts. Additional contracts would need to be negotiated if non-radiologically contaminated material is to be sent to a facility not currently under contract. A number of properly permitted facilities are available in the United States that could serve as locations for disposal of some or all of the potential waste streams. A review of specific facilities that could receive waste streams from the Luckey site is provided as Appendix 4A. Additionally, a number of licensed transporters should be available to haul properly documented waste.

Since several facilities may be contracted to receive different waste streams, a mechanism would need to be in place to ensure that the waste was properly segregated and that the regulatory agencies are satisfied with the procedures.

Cost: The cost of disposal at a licensed or permitted disposal facility is moderate, compared to the cost of constructing a new cell with similar features and performance. There would be no long-term O&M costs since soil contaminated above cleanup goals would be removed from the site.

Off-site disposal at an existing facility is retained.

4.3.10.2 Off-site Disposal at a New Engineered Structure

Effectiveness: This option involves the design and construction of a new off-site engineered structure disposal facility. The facility would be designed and constructed to receive the waste streams to be disposed. This would be an effective option for physically separating contaminated materials from potential receptors.

Implementability: Implementability concerns for a new off-site engineered structure disposal facility include locating an area in which to construct the facility and finding a site that meets the engineering design criteria. The implementation time required to acquire additional land, perform site suitability studies, obtain approvals, and address potential opposition from stakeholders would likely be significant and would not allow for a timely remedy to protect public health and the environment. Furthermore, public stakeholders prefer the use of existing disposal facilities, provided that there is adequate capacity, rather than creating a new disposal facility.

Cost: A new off-site disposal cell would have high capital and moderate to high O&M costs. There would be no disposal fees associated with a dedicated off-site facility. Due to the relatively small volume of material to be disposed, it may not be justifiable from a cost perspective to construct a new offsite disposal facility.

Given the cost consideration above, off-site disposal in a new engineered structure was eliminated from further consideration.

4.3.10.3 Handling (Soils)

Effectiveness: The transportation options for hauling contaminated soils involve the individual or combined use of trucks, railcars, or barges for shipment from the site to the selected disposal facility. Trucks have been used extensively at other FUSRAP sites and are very effective due to their adaptability to site and route conditions. Trucks become less effective with greater haul distances due to safety concerns. Railcars are effective and also have been used extensively at other FUSRAP sites. However, there is no rail spur at the Luckey site, so one would either have to be built or material would have to be trucked to a loading facility. Barges are effective if the originating site and the disposal site are located near navigable waterways with loading and off loading capabilities. Due to the distance of the Luckey site and existing disposal facilities from navigable waterways, barges are eliminated from further consideration.

Implementability: The use of trucks or railcars, individually or in combination with each other, is commonly implemented for transporting contaminated soils. Truck and rail transportation uses readily available resources and conventional transportation equipment. The use of railcars alone would be difficult to implement due to the location of the existing rail service (no rail spur is immediately accessible at the Luckey site). Currently, the closest rail service line is approximately 2 miles from the site and installing a service line for the sole purpose of removing the on-site soils would require obtaining multiple easements from property owners. Therefore, an off-site staging area is needed to transfer waste loads from trucks to railcars. Off-site staging areas have been successfully used and operated at other FUSRAP sites. The existing disposal facilities currently have capabilities for off-loading railcars, so no additional staging would be required. It is currently estimated that 10 to 12 trucks would travel to and from the off-site staging area each day. A transportation assessment has been prepared (Appendix 4B) to evaluate traffic and load capacity of local roads as well as the distance to potential staging areas. In all three cases, waste would be manifested or a bill-of-lading secured with all supporting documentation and a licensed transporter secured.

Cost: The cost of transporting soils by truck would be moderate to high, depending on distance of haul. The cost of obtaining permits, transporters, and acquiring a staging site for hauling waste by railcar would be moderate. The cost of obtaining permits, transporters, and acquiring staging sites for hauling waste by barge would be high.

Both trucks and railcars are retained.

4.3.10.4 On-site Engineered Structure

This option involves the design and construction of a new disposal facility on site.

Effectiveness: This would be an effective option for physically separating contaminated materials from potential receptors. Effectiveness concerns for on-site disposal include the ability of the site to meet engineering design criteria (i.e., geologic conditions, foundation soils, groundwater, seismic activity) for the siting and licensing of a disposal cell in the state of Ohio.

Implementability: Siting studies, facility design, environmental assessments and/or environmental impact statements, and public review would be required prior to implementation of this option. As stated previously, the public generally would have concerns regarding a new on-site disposal facility if a disposal facility with adequate capacity existed elsewhere. These requirements could result in unacceptable delays. During the site selection process, activities related to the construction and operation of the facility would be analyzed, and studies would be required to eliminate or minimize unacceptable impacts. The State of Ohio siting and licensing process would render this alternative technology difficult to implement administratively. The government may consider purchasing at least a portion of the property, but it may be difficult and require long term surveillance, monitoring, and maintenance requirements.

Cost: A new on-site disposal cell would have high capital and moderate to high O&M costs because of the long-term need for maintenance. There would be no disposal fees associated with a dedicated on-site facility.

On-site disposal in a new engineered structure will not be considered further due to the administrative difficulty of meeting the substantive requirements of constructing such a facility under Ohio Law.

4.3.11 Disposal and Handling (Groundwater)

Disposal and handling of groundwater provide for the handling of the water after its extraction from the aquifer and its eventual disposal after treatment.

4.3.11.1 Off-site Disposal/Discharge (Groundwater)

Effectiveness: Off-site disposal of groundwater to a POTW or other wastewater disposal facility is considered effective. This option consists of using tanker trucks to transport either treated or untreated water to the facility for disposal.

Implementability: Off-site disposal of groundwater to a POTW or other wastewater disposal facility is an easily implemented option.

Cost: Costs for off-site disposal can be moderate to high, if treatment is required, and can vary depending on the distance to the nearest facility. For the Luckey site, the nearest available facilities are in

the Bowling Green and Toledo areas, which are approximately 12 and 20 miles away, respectively. This is a feasible distance.

Off-site disposal is retained.

4.3.11.2 Handling (Groundwater)

Effectiveness: The transportation options for hauling contaminated groundwater involve the individual or combined use of trucks, railcars, or barge shipment from the site to the selected disposal facility. Tanker trucks have been used at other FUSRAP sites and are very effective due to their adaptability to site and route conditions. Trucks become less effective with greater haul distances due to safety concerns. Railcars are effective for long distances. However, there is no rail spur at the Luckey site so one would either have to build a spur or material would have to be trucked to a loading facility. Barges are effective if the originating site and the disposal site are located near navigable waterways with loading and off loading capabilities. Due to the distance from the Luckey site and existing disposal facilities to navigable waterways, barges were eliminated from further consideration.

Implementability: Truck and rail transportation use readily available resources and conventional transportation equipment. The use of railcars alone would be difficult to implement due to the location of the existing rail service (no rail spur is immediately accessible at the Luckey site). Currently, the closest rail service line is approximately 2 miles from the site and installing a service line would require obtaining multiple easements from property owners. Therefore, an off-site staging area is needed to transfer waste loads from trucks to railcars. Off-site staging areas have been successfully used and operated at other FUSRAP sites. Depending on the wastewater facility, an additional staging area might be required. In addition, the receiving wastewater facility generally will be located proximal to the site (within 20 miles), rendering railcar service inefficient for such a short haul distance. Barges would be less implementable than railcars due to greater haul distances required to reach existing barge facilities and since multiple off-site staging areas would have to be produced. In all three cases, waste would be manifested and a licensed transporter secured. Due to the long haul distance to transfer locations, railcars and barges would not be implemented easily.

Cost: The cost of transporting wastewater by truck would be moderate to high, depending on distance of haul. The cost of obtaining permits, transporters, and acquiring a staging site for hauling waste by railcar would be moderate. The cost of obtaining permits, transporters, and acquiring staging sites for hauling waste by barge would be high.

Trucks will be retained. Railcars and barges were eliminated from further consideration due to increased costs and haul distances associated with these options.

4.3.11.3 On-site Disposal/Discharge (Groundwater)

Effectiveness: On-site disposal options include discharge to surface water and deep well injection. Both are effective methods for the discharge of treated water. Deep well injection also may be used for discharge of untreated water to a zone considerably deeper than and hydrogeologically isolated from the aquifer. These process options are retained for further consideration.

Implementability: Implementability for on-site disposal will depend upon the requirements for permits. An NPDES permit is not required for discharge to surface waters; however, the substantive requirements of a permit must be met. Other permits may be needed for deep well injection.

Cost: Operational costs for on-site disposal would be low for discharge to surface water and low to moderate for deep well injection.

On-site disposal is retained.

4.4 RETAINED PROCESS OPTIONS

The following summarizes the process options that have been retained through the screening process. These options are assembled, as appropriate, into alternatives in Section 5 of this FS to address contaminants in soils and groundwater at the Luckey site.

4.4.1 Soil

The following process options for soil have been retained for use individually or in combination in the development of alternatives:

- No Action
- Physical Mechanisms
- Legal and Administrative Mechanisms
 - Governmental Controls
 - Proprietary Controls
 - Informational Devices
- Environmental Monitoring
 - Soil
 - Groundwater
 - Surface Water
 - Air
- Containment (Capping)
- Removal (Soil Excavation)
- Treatment (Soil Washing)
- Off-site Disposal at an Existing Facility
- Handling (Truck)
- Handling (Railcar).

4.4.2 Groundwater

The following process options for groundwater have been retained for use individually or in combination in the development of alternatives:

- No Action
- Physical Mechanisms
- Legal and Administrative Mechanisms
 - Governmental Controls
 - Proprietary Controls
 - Informational Devices
- Environmental Monitoring (Groundwater)
- Removal (Vertical Wells)
- Treatment
 - Adsorption
 - Ion Exchange
 - Chelation

- Electrokinetics
- Monitored Natural Attenuation
- Geochemical Immobilization
- Off-site Disposal/Discharge to POTW
- Handling (Truck)
- On-site Disposal/Discharge to Surface Water
- On-site Disposal/Discharge by Deep Well Injection

Adsorption is a proven and available technology for all three COCs. Ion exchange, although effective, produces a potentially hazardous waste stream. Electrokinetics is a relatively new technology that may be able to effectively and relatively quickly address COCs in groundwater within the unconsolidated overburden. Chelation is an in situ technology used to enhance solubility or mobility of the COCs and may be used to increase the effectiveness of electrokinetics. MNA is effective for the COCs as a result of the naturally occurring processes of dispersion, diffusion, and sorption, which reduce COC concentrations as they migrate vertically and horizontally through the groundwater flow system. Implementation of geochemical immobilization may mobilize other metals, such as manganese and lead. At the Luckey site, manganese, although not an AEC-related constituent, already exceeds the secondary MCL in groundwater and may be mobilized by the reduction process used to immobilize uranium.

Table 4.1. Overview of Luckey Site General Response Actions

Environmental Media	General Response Actions	Remedial Technologies	Process Options
Soil	No Action	None	None. Required to be carried through the CERCLA analysis.
	Land Use Controls	Administrative and Legal Mechanisms	Governmental controls, enforcement tools, informational devices, proprietary controls
	Monitoring	Physical mechanisms Environmental Moni.	Physical barriers, permanent markers, security personnel Soil, groundwater, surface water, sediment, air
	Containment	Capping with consolidation	Native soil, clay, asphalt, concrete, synthetic liner, multi-layered, concrete
	Removal	Soil excavation	Soil excavation with earth moving equipment
	Treatment	Physical	Encapsulation, thermoplastic solidification, solidification/stabilization, vitrification, soil washing, soil sorting,
		Chemical	Chemical oxidation/reduction, chemical soil washing, hydrolysis, neutralization, stabilization
		Biological Thermal	Biodegradation Incineration
Groundwater	No Action	None	None. Required to be carried through the CERCLA analysis.
		Administrative and Legal Mechanisms	Governmental controls, enforcement tools, informational devices, proprietary controls,
		Physical mechanisms Environmental Moni.	Physical Barriers Groundwater monitoring
	Containment	Barriers	Sheet piles, geosynthetic membrane, slurry walls, jet grouting, soil freezing, and hydraulic barriers
	Removal	Extraction wells	Vertical wells and horizontal wells
	Ex Situ Treatment	Physical	Adsorption, air stripping/packed tower, evaporation ponds, crystallization, flocculation/precipitation, physical catalysis, dissolved air flotation, ultra/micro/nanofiltration, reverse osmosis, ion exchange, sedimentation
		Chemical	Chemical coagulation/precipitation, chemical catalysis
	In Situ Treatment	Physical	Permeable treatment walls, liquid gas extraction, vacuum extraction, air sparging, chelation, electrokinetics, MNA
		Chemical	Chemical coagulation/precipitation, chemical catalysis, chemical hydrolysis, geochemical immobilization
		Biological	Bioremediation, biological sorption
		Thermal	Incineration, distillation, steam stripping, evaporation, super critical water oxidation, and wet air oxidation.
	Disposal and Handling	On-site disposal	Discharge to surface water, deep well injection
		Off-site disposal	Dispose/discharge to POTW or other disposal facility
		Transportation	Truck, railcar, or barge
		Beneficial Reuse	Land spraying/irrigation, reclamation/recycle/reuse

Table 4.2. Initial Screening of Technology Types and Process Options for Soils

General Response Action	Technology Type	Process Options	Description	Screening Comments
No Action	None	None	No action is taken to implement remedial technologies to reduce hazard to potential human or ecological receptors.	Required to be carried through the CERCLA analysis.
Land Use Controls	Administrative and Legal Mechanisms	Governmental Controls	Land use controls may be placed on the site by a government entity to control the types of land use allowed. Zoning restrictions can be used to prohibit development or rezoning to residential use.	Potentially applicable. May be used to limit the future land use options, depending on the alternative chosen and the amount of contamination left in place.
		Enforcement Tools	Administrative orders or consent decrees that can be used to restrict the use of land.	Not applicable because USACE does not have enforcement authority.
		Informational Devices	Registries, deed notices, and/or advisories may be used to notify future land owners of residual or capped contamination.	Potentially applicable. May be used to limit the future land use options, depending on the alternative chosen and the amount of contamination left in place.
		Proprietary Controls	Contractual mechanisms based on private property law (e.g., deed covenants, easements) may be placed on the site to prevent a landowner from disturbing contaminated soil, sediment, or groundwater.	Potentially applicable. May be used to limit the future land use options, depending on the alternative chosen and the amount of contamination left in place.
	Physical mechanisms	Physical barriers, permanent markers, and/or security personnel	Access to an area can be restricted through the use of fences, signs, or security surveillance.	Potentially applicable. Will be used in conjunction with all alternatives during implementation to prevent incidental exposure to contaminated soil.
Monitoring	Environmental Monitoring	Soil, groundwater, surface water, sediment, and air	Various types of environmental monitoring may be instituted to detect contaminant migration.	Potentially applicable. Required with remedies where waste is left in place. May be used during or after construction activities to ensure contaminants are not migrating from source area or to verify remedies are effective.
Containment	Capping	Native soil, clay, synthetic liner, multi-layered, asphalt or concrete	Area of contamination covered with a layer of clean soil, clay, synthetic liner, multiple layers of different media, asphalt, or concrete.	Potentially applicable. Requires long-term maintenance. Limits future use.
Removal	Soil excavation	Earth moving equipment	Mechanically or hydraulically operated units such as excavators, front-end loaders, and bulldozers, and/or hand tools are used for trenching or other subsurface excavation.	Potentially applicable for excavating, loading, and moving contaminated soils.
Treatment	Physical treatment	Encapsulation	Ex situ physical encapsulation of wastes in an organic binder or resin.	Not applicable due to the large volume of fine grained soils present at the site.



Indicates technologies eliminated from further consideration.

Table 4.2. Initial Screening of Technology Types and Process Options for Soils

General Response Action	Technology Type	Process Options	Description	Screening Comments
Treatment cont'd.	Physical treatment cont'd.	Thermoplastic Solidification	Ex situ process whereby waste is sealed in asphalt bitumen, paraffin, or polyethylene matrix.	Not applicable due to the large volume of fine grained soils present at the site.
		Stabilization/Solidification	Can be carried out in situ or ex situ. Soil solidified using various cements and silicate-based mixtures as solidifying agents. The resulting solids are resistant to leaching.	Potentially applicable. Potentially limits future reuse if done in situ. Typically results in increased volumes.
		Vitrification	Can be carried out in situ or ex situ. Inorganic and nonvolatile metallic constituents are immobilized in a glass matrix.	Ex situ vitrification is potentially applicable. In situ vitrification limits future reuse of site and effectiveness is difficult to verify. In situ vitrification is eliminated from further consideration.
		Soil washing	Ex situ physical separation of impacted material in an aqueous base, concentrating COCs.	Potentially applicable. Typically requires other physical and chemical processes to more effectively treat of soils.
		Soil sorting	Physical ex situ separation of impacted materials based on radionuclide concentration and/or particle size.	Not applicable due to the large volume of fine-grained soils present at the site. Process ineffective for beryllium-contaminated soils.
	Chemical Treatment	Chemical oxidation/reduction	Appropriate chemicals added to raise or lower the oxidation state of the reactant.	Not applicable for COCs identified at the Luckey site. Potentially large amounts of chemical waste products will be generated and require additional waste treatment and disposal.
		Chemical soil washing	A process similar to physical soil washing; however, chemicals are used as the wash fluid.	Not applicable for COCs identified at the Luckey site. Produces extraneous waste stream that may be difficult to treat.
		Hydrolysis	Involves a reaction with an organic chemical and water or hydroxide ion to break the chemical down to a simpler, less toxic form.	Not applicable for COCs identified at the Luckey site.
		Neutralization	Chemicals are injected into saturated and/or unsaturated soil strata to adjust the pH of the soil and/or groundwater.	Not applicable for COCs identified at the Luckey site.
		Stabilization	Chemicals added to bind waste into a form that is resistant to leaching of contaminants.	Not applicable for COCs identified at the Luckey site.
	Biological Treatment	Biodegradation	Processes include slurry-phase and solid-phase biodegradation, and anaerobic biodegradation. These are destruction or transformation techniques in which a favorable environment is created for microorganisms to grow and use the contaminants as a food or energy source.	Not applicable for COCs identified at the Luckey site.



Indicates technologies eliminated from further consideration.

Table 4.2. Initial Screening of Technology Types and Process Options for Soils

General Response Action	Technology Type	Process Options	Description	Screening Comments
Treatment cont'd.	Thermal Treatment	Incineration	Processes use heat to volatilize contaminants. There are various forms of thermal treatment technologies as follows: incineration, infrared, retorting, pyrolysis, low temperature thermal desorption.	Not applicable for COCs identified at the Luckey site.
Disposal and Handling	On-site Disposal	On-site engineered structure	Design and construct a disposal facility on site.	Potentially applicable.
		On-site soil disposal	The disposal of soil that has been treated in place utilizing site closure and post-closure techniques.	Potentially applicable only when used in conjunction with in situ treatment. Ohio law requires radiological contamination to be below background for on-site disposal.
	Off-site Disposal	Existing federal or commercially licensed or permitted disposal facility	Transport treated and/or untreated soils meeting waste acceptance criteria to an off-site disposal facility.	Potentially applicable if contaminants are within acceptance criteria.
		New engineered structure	Construct an engineered structure, such as a tumulus disposal trench, above ground or underground vault, underground silos, etc.	Potentially applicable.
	Handling	Truck, railcar or barge.	Trucks, railcars and/or barges could be used to transport soil waste to disposal facility via roadway, railway or waterway.	Trucks would be more suited for short to medium distances. Railcars would be more suited for long distance. Barges are suited for transportation over large bodies of water and/or where there is more direct water route.



Indicates technologies eliminated from further consideration.

Table 4.3. Initial Screening of Technology Types and Process Options for Groundwater

General Response Action	Technology Type	Process Options	Description	Screening Comments
No Action	None	Not Applicable	No action is to be taken to implement remedial technologies to reduce hazards to potential human or ecological receptors.	Required to be carried through the CERCLA analysis.
Land Use Controls	Administrative and Legal Mechanisms	Governmental Controls	Land use controls may be placed on the site by the local government to control the types of land use allowed. Zoning restrictions can be used to prohibit development or rezoning to residential use.	Potentially applicable. May be used to limit the future land use options, depending on the alternative chosen and the amount of contamination left in place.
		Enforcement Tools	Administrative orders or consent decrees that can be used to restrict the use of groundwater.	Not applicable because USACE does not have enforcement authority.
		Informational Devices	Registries, deed notices, and/or advisories may be used to notify future land owners of groundwater contamination.	Potentially applicable. May be used to limit the future groundwater use options, depending on the alternative chosen and the amount of contamination left in place.
		Proprietary Controls	Contractual mechanisms based on private property law (e.g., deed covenants, easements) may be placed on the site to prevent a landowner from using groundwater.	Potentially applicable. May be used to limit the future groundwater use options, depending on the alternative chosen and the amount of contamination left in place.
	Physical mechanisms	Physical barriers, permanent markers, and/or security personnel	Access to an area can be restricted through the use of fences, signs, or security surveillance.	Potentially applicable. Will be used in conjunction with all alternatives during implementation to prevent incidental exposure to contaminated groundwater.
Monitoring	Environmental Monitoring	Groundwater monitoring	Perform water quality analyses to monitor contaminant migration and assess future environmental impacts.	Potentially applicable. May be used to assist with contaminant control during remedial action activities and to monitor performance of the treatment alternative or to monitor natural attenuation.
Containment	Vertical Barriers	Sheet Piles, Geosynthetic Membrane, Slurry Walls, Jet Grouting, Soil Freezing, and Hydraulic Barriers	Vertical barriers minimize contaminant migration in groundwater by providing a physical barrier to the natural flow path of an aquifer. Although all barrier technologies have a similar application, they have widely varying designs and installation procedures.	Potentially applicable.
Removal	Groundwater Removal via Extraction wells	Vertical Wells	Vertical wells remove groundwater from aquifers or perched water zones.	Potentially applicable. Dependent on properties of aquifer and well construction. May be used in conjunction with other remedial technologies.



Indicates technologies eliminated from further consideration.

Table 4.3. Initial Screening of Technology Types and Process Options for Groundwater

General Response Action	Technology Type	Process Options	Description	Screening Comments
Removal cont'd.	Groundwater Removal via Extraction wells cont'd.	Horizontal Wells	Horizontal well screens provide greater surface area in contact with the contaminated soil or groundwater; fewer wells may be required. Directionally drilled horizontal wells can be installed beneath buildings and other surface structures.	Potentially applicable.
Ex Situ Treatment	Physical Treatment	Adsorption	Contaminants are displaced from one medium to another with activated carbon alumina, or other media.	Potentially applicable for metals and radionuclides. Depends on concentrations of dissolved constituents in groundwater.
		Air Stripping/Packed Tower	Large volumes of air are mixed with water in a packed tower to promote partitioning of VOCs to air.	Not applicable for COCs.
		Evaporation Ponds (natural)	Water is evaporated to concentrate contaminants present in liquids.	Not applicable for concentrations of contaminants at Luckey.
		Crystallization	Process in which certain solutes crystallize out from a saturated solution when the solvent is cooled.	Not applicable for COCs. Requires chemical addition and is very energy intensive.
		Flocculation/Precipitation	Physical process to promote flocculation of colloids. The resultant particles are too large to remain in suspension.	Potentially applicable for metals and radionuclides.
		Physical Catalysis	A physical process used to accelerate a chemical change of a contaminant.	Not applicable. This process is generally not feasible for metals.
		Dissolved Air Flotation	Minute air bubbles, introduced by pressurization/depressurization means, rise to the surface carrying low-density solids.	Not applicable for dissolved metals or radionuclides.
		Ultra/Micro/Nanofiltration	A membrane filtration process that separates high molecular weight solutes or colloids from their surrounding media.	Not applicable for COCs.
		Reverse Osmosis	Pressure is applied to force flow from dilute to concentrated solution through a membrane that is impermeable to a solute (dissolved ions).	Potentially applicable.
		Ion Exchange	Contaminated water is passed through a resin bed where ions are exchanged between resin and water.	Potentially applicable for metals. Spent resin generates a concentrated waste stream.
		Sedimentation	Suspended particles are allowed to settle depending on the particle diameter and specific gravity in a basin or pond enclosure.	Potentially applicable as a post treatment step.
	Chemical Treatment	Coagulation/Precipitation	Chemical processes that precipitate particles that are too small for gravitational settling by satisfying particle charge.	Potentially applicable for metals.



Indicates technologies eliminated from further consideration.

Table 4.3. Initial Screening of Technology Types and Process Options for Groundwater

General Response Action	Technology Type	Process Options	Description	Screening Comments
Ex Situ Treatment cont'd.	Chemical Treatment cont'd.	Chemical Catalysis	The addition of a substance to accelerate or permit a chemical change of contaminant that is not permanently affected by the reaction.	Potentially applicable for uranium and lead, but usually a preliminary step to other treatment processes.
In Situ Treatment	Physical-Treatment	Permeable Treatment Walls	Trenches are excavated perpendicular to groundwater flow and filled with a reactive permeable natural or synthetic medium to treat or adsorb contaminants.	Not applicable due to uncertain variations in flow gradient. Primarily used for chlorinated organic compounds.
		Liquid Gas Extraction	Uses gases (CO ₂ , propane) to alter properties of solvents to make extraction of organics more rapid and efficient.	Not applicable for COCs (i.e., metals).
		Vacuum Extraction	Vacuum pumps are connected via a pipe system to a series of production wells to remove VOCs from groundwater.	Not applicable for COCs (i.e., metals).
		Air Sparging	Horizontal wells are placed in saturated soil strata where air is introduced to cause the volatilization of organic contaminants.	Not applicable for COCs (i.e., metals).
		Chelation	Chelating molecules form ligands with metal ions and are used to keep metals in solution and aid in dissolution.	Potentially applicable for metals and radionuclides.
		Electrokinetics	Electrodes are installed and electrical power used to drive contaminants to the anode for collection in an electrolyte solution.	Potentially applicable for uranium, lead and beryllium.
		Monitoring Natural Attenuation (MNA)	Passive physical treatment process.	Potentially applicable. Use of MNA as a component of a remedial alternative is appropriate along with the use of other measures, such as source control or containment measures.
	Chemical Treatment	Coagulation/Precipitation	The process by which particle charge is satisfied as a result of the chemical added to reduce the solubility of the contaminant.	Potentially applicable for metals.
		Chemical Catalysis	The addition of a substance to accelerate a chemical change of contaminant that is not permanently affected by the reaction.	Potentially applicable for uranium and lead, but usually a preliminary step to other treatment processes.
		Chemical Hydrolysis	Chemical decomposition by hydrolytic reactions.	Not applicable for COCs.
		Geochemical Immobilization	Wells are drilled and a reducing agent is injected into the formation to chemically change the solubility of uranium	Potentially applicable.
	Biological Treatment	Bioremediation	Groundwater is amended with oxygen, nutrients, and microorganisms (optional).	Potentially applicable for uranium and lead, but not beryllium.
		Biological Sorption	Biosorption process uses various active and inactive microorganisms such as algae and fungi to remove heavy metal ions from aqueous solutions.	Potentially applicable for uranium and lead, but not beryllium.



Indicates technologies eliminated from further consideration.

Table 4.3. Initial Screening of Technology Types and Process Options for Groundwater

General Response Action	Technology Type	Process Options	Description	Screening Comments
In Situ Treatment cont'd.	Thermal Treatment	Incineration, distillation, steam stripping, evaporation, super critical water oxidation, and wet air oxidation	Processes use the liquid/gas interface to remove contaminants and oxygen to change chemical compounds.	Not applicable. Energy intensive. More applicable to organic compounds.
Disposal/ Handling	On-Site Disposal/ Discharge	Discharge to Surface Water	Extracted and treated water discharged to surface water in the vicinity of the site.	Potentially applicable. Although a permit would not be required the substantive requirements of a NPDES permit must be met.
		Deep Well Injection	Treated or untreated ground water is injected into an isolated zone.	Potentially applicable. Requires permitting.
	Off-Site Disposal/ Discharge	Dispose/Discharge to POTW or Other Disposal Facility	Discharge treated water to POTW or other treatment or disposal facility.	Potentially applicable.
	Handling	Truck, Railcar or Barge.	Trucks, railcars and/or barges could be used to transport groundwater waste to disposal facility via roadway, railway or waterway.	Potentially applicable. Trucks would be more suited for short to medium distances. Railcars and barge would be more suited for long distance.
	Beneficial Reuse	Land Spraying/Irrigation	Typically used for organic wastewaters. Treated effluent is sprayed on land for irrigation purposes.	Not applicable.
		Reclamation/ Recycle/Reuse	Concentrated contaminants are reclaimed as commercial products by recycling.	Not applicable.



Indicates technologies eliminated from further consideration.

Table 4.4. Detailed Screening of Technology Types and Process Options for Soils

General Response Action	Technology Type	Process Options	Effectiveness	Implementability	Cost	Screening Results
No Action	None	Not applicable	Not effective. Required to be carried through the CERCLA analysis.	Easy	Low	Retained
Land Use Controls	Physical mechanisms	Physical barriers, permanent markers, security personnel	Effective for short term in reducing exposure.	Easy	Low to moderate	Retained
	Administrative and Legal Mechanisms	Government controls	Effective for mid to long term.	Easy to moderate	Moderate	Retained
		Informational Devices	Effective for short term.	Easy to moderate	Low	Retained
		Proprietary Controls	Effective for mid to long term.	Easy to difficult	Moderate	Retained
Monitoring	Environmental Monitoring	Soil, groundwater, surface water, and air	Documents site conditions. Does not reduce risk but will act as a preventative measure by providing information concerning changes in conditions.	Easy	Low	Retained
Containment	Capping	Native soil, clay, synthetic liner, multi-media, asphalt or concrete	Effective, but requires maintenance.	Easy to moderate	Low to moderate	Retained
Removal	Soil Excavation	Earth moving equipment	Effective	Easy in most areas	Moderate to high	Retained
Treatment	Physical Treatment	Solidification	Effective in stabilizing contaminants but likely to increase volumes.	Easy to moderate	Moderate to high	Eliminated.
		Vitrification (ex situ)	Effective in reducing mobility, but still requires disposal at a licensed facility.	Moderate to difficult to implement.	High	Eliminated.
		Soil washing	Effectiveness in removing contaminants uncertain pending treatability studies.	Easy	Moderate to high	Retained
Disposal and Handling	Off-site Disposal	Existing federal or commercially licensed or permitted disposal facility	Effective	Easy	Moderate	Retained
		New engineered structure	Effective	Difficult to implement due to siting requirements.	Moderate to high	Eliminated.
	Handling	Truck	Effective for short to medium distances.	Easy	Moderate to high	Retained



Indicates technologies eliminated from further consideration.

Table 4.4. Detailed Screening of Technology Types and Process Options for Soils

General Response Action	Technology Type	Process Options	Effectiveness	Implementability	Cost	Screening Results
Disposal and Handling cont'd.	Handling cont'd.	Railcar	Effective for long distances.	Easy to moderate to implement. An off site staging area must be put in place.	Moderate	Retained
		Barge	Effective with load/unload points close to docks.	Easy	High	Eliminated.
	On-site Disposal	New engineered structure	Effective	Difficult to implement due to siting requirements.	Moderate to high	Eliminated.



Indicates technologies eliminated from further consideration.

4.5. Detailed Screening of Technology Types and Process Options for Groundwater

General Response Action	Technology Type	Process Options	Effectiveness	Implementability	Cost	Screening Results
No Action	None	None	Not effective. Required to be carried through the CERCLA analysis.	Easy	Low	Retained
Land Use Controls	Physical mechanisms	Physical barriers, permanent markers, security personnel	Effective for short term in reducing exposure.	Easy	Low	Retained
	Administrative and Legal Mechanisms	Government controls	Effective for mid to long term.	Easy to moderate	Moderate	Retained
		Informational Devices	Effective for short term.	Easy to moderate	Low	Retained
		Proprietary Controls	Effective for mid to long term.	Easy to difficult	Moderate	Retained
Monitoring	Environmental Monitoring	Groundwater monitoring	Documents site conditions. Does not reduce risk but will act as a preventative measure by providing information concerning changes in conditions.	Easy	Low	Retained
Containment	Vertical Barriers	Sheet Piles, Geosynthetic Membrane, Slurry Walls, Jet Grouting, Soil Freezing, and Hydraulic Barriers	Difficult to produce an effective seal due to fractured bedrock. Also difficult to design with no defined plume	Easy to moderate depending on type of barrier. Hard to implement because no defined plume.	Moderate to high depending on extent	Eliminated.
Removal	Groundwater Removal via Extraction Wells	Vertical Wells	Effective if accompanied by source removal.	Easy	Low	Retained
		Horizontal Wells	Effective for large areas of contamination.	Hard to implement because no defined plume.	Low	Eliminated.
Ex Situ Treatment	Physical Treatment	Adsorption	Effective	Easy	Moderate	Retained



Indicates technologies eliminated from further consideration.

4.5. Detailed Screening of Technology Types and Process Options for Groundwater

General Response Action	Technology Type	Process Options	Effectiveness	Implementability	Cost	Screening Results
Ex Situ Treatment cont'd.	Physical Treatment cont'd.	Flocculation/Precipitation	Effectiveness uncertain; would require pilot study to determine if it can be effective; usually part of treatment train with coagulation.	Easy	Low to high depending on pre and post treatment steps.	Eliminated.
		Reverse Osmosis	Low effectiveness; pilot study needed to determine effectiveness with changes in temperature, pH, etc.	Easy depending on retention times, fouling, and degradation.	Moderate to high depending on complexity of membrane layers.	Eliminated.
		Ion Exchange	Effective	Easy	Moderate to high depending on resin cost	Retained
		Sedimentation	Effective only following pretreatment step (no pretreatment step retained).	Easy	Low to moderate	Eliminated.
	Chemical Treatment	Coagulation/Precipitation	Effective for uranium and lead, but unproven for beryllium.	Easy to moderate depending on defined plume.	Low to high depending on pre and post treatment steps.	Eliminated.
		Chemical Catalysis	Effective for uranium and lead, but unproven for beryllium.	Easy	Moderate	Eliminated.
In Situ Treatment	Physical	Chelation	Effective for uranium and lead, but unproven for beryllium.	Easy	Moderate to high	Retained
		Electrokinetics	Effective for uranium, lead and beryllium. Power requirements and durations uncertain pending treatment studies	Easily implemented	Moderate	Retained
		Monitoring Natural Attenuation (MNA)	Effective for beryllium, lead, and uranium.	Easy	Low	Retained
	Chemical	Coagulation/Precipitation	Effective for uranium and lead, but unproven for beryllium.	Easy	Moderate to high	Eliminated.



Indicates technologies eliminated from further consideration.

4.5. Detailed Screening of Technology Types and Process Options for Groundwater

General Response Action	Technology Type	Process Options	Effectiveness	Implementability	Cost	Screening Results
In Situ Treatment cont'd.	Chemical cont'd.	Chemical Catalysis	Effective for uranium and lead, but unproven for beryllium.	Easy	Moderate	Eliminated.
		Geochemical Immobilization	Effective for uranium but may mobilize lead and manganese.	Easily implemented	Low	Eliminated.
	Biological Treatment	Bioremediation	Varying effectiveness for uranium and lead, but unproven for beryllium.	Easy to moderate depending on type used.	Low to moderate depending on effectiveness.	Eliminated.
		Biological Sorption	Effective for uranium and lead, but unproven for beryllium.	Easy	Low to moderate depending on effectiveness.	Eliminated.
Disposal/Handling	Off-Site Disposal/ Discharge	Dispose/Discharge to POTW or Other Disposal Facility	Effective	Easy depending on distance to facility.	Moderate to high depending on disposal/discharge requirements.	Retained
	Handling	Truck	Effective for short to medium distances.	Easy	Moderate to high	Retained
		Railcar	Effective for long distances.	Difficult to implement due to short distance to disposal facility (approximately 20 miles).	Moderate	Eliminated.
		Barge	Effective with load/unload points close to docks.	Difficult due to the long distant between the barge loading/unloading docks and the disposal facility.	High	Eliminated.
	On-site Disposal/ Discharge	Discharge to Surface Water	Effective	Easy	Low	Retained
		Deep Well Injection	Effective	Moderate to high depending on required permits.	Low to moderate	Retained



Indicates technologies eliminated from further consideration.

5.0 DEVELOPMENT OF REMEDIAL ALTERNATIVES

This section describes the remedial alternatives assembled for the Luckey site. The remedial alternatives were constructed by combining general response actions, technology types, and process options retained from the screening processes described in the previous section. Remedial alternatives should assure adequate protection of human health and the environment, achieve RAOs, meet ARARs, and permanently and significantly reduce the volume, toxicity, and/or mobility of site-related contaminants.

The remedial alternatives presented here address the soil and groundwater contamination at the Luckey site. The alternatives encompass a range of potential actions:

- Alternative 1: No Action (Soils and Groundwater)
- Alternative 2: Limited Action (Soils and Groundwater)
- Alternative 3: Consolidation and Capping (Soils)
- Alternative 4: Excavation of Soils and Off-site Disposal (Soils) ~ Industrial Land Use
- Alternative 5: Excavation of Soils and Off-site Disposal (Soils) ~ Unrestricted Land Use
- Alternative 6: Excavation of Soils, Treatment, and Off-site Disposal (Soils) ~ Unrestricted Land Use
- Alternative 7: Monitored Natural Attenuation (Groundwater) ~ Unrestricted Land Use
- Alternative 8: Active Groundwater Treatment – Ex Situ (Groundwater) ~ Unrestricted Land Use
- Alternative 9: Electrokinetics (Groundwater) ~ Unrestricted Land Use.

Alternative 1 is the no-action response required under the NCP and is inclusive of both soil and groundwater. Alternative 2 also is inclusive of soil and groundwater and relies on limited site improvements, and natural attenuation of impacted groundwater in conjunction with land use controls. No source control or removal actions are implemented under Alternative 2.

Alternatives 3, 4, 5, and 6 address soils and utilize short-term monitoring in combination with other containment, removal, and/or treatment technologies. Alternatives 3 and 4 also would require long-term monitoring and five-year reviews because impacted soils would remain on site above limits, not allowing unlimited use of or unrestricted exposure at the property. Alternative 3 uses consolidation combined with containment technologies. Removal technologies are included in Alternatives 4, 5, and 6. Alternatives 4 and 5 rely primarily on off-site disposal. Alternative 6 utilizes removal and off-site disposal combined with soil treatment.

Groundwater treatment alternatives are presented in Alternatives 7, 8, and 9 and include MNA, active remediation (pump and treat), and electrokinetics, respectively. Long-term monitoring and five-year reviews would be conducted until limits in groundwater are achieved that would allow for the unrestricted use of the property. These nine remedial alternatives are described below and are summarized in Table 5.1. The remedy selected for the Luckey site will pair one of the groundwater alternatives (7, 8, or 9) with one of the soil alternatives (3, 4, 5, or 6) unless Alternatives 1 or 2 are selected. The contaminant source in soils must be removed in order for the groundwater alternatives to be successful.

Time periods for environmental monitoring are specific to each alternative. The length of time depends upon the relevant ARARs and the specific technologies employed under each alternative. For the no action alternative, the assumed length of time is zero. For Alternatives 2 and 3, where radioactive contamination remains on site, the length of time is assumed to be 1,000 years, based upon the general provisions of 10 CFR Part 20 Subpart E regarding radioactive contamination. For Alternative 4, where

beryllium and lead would remain on site above unrestricted land use cleanup goals, the length of time also is assumed to be 1,000 years. This is consistent with the length of time assumed for Alternatives 2 and 3. For Alternatives 5 and 6, where soil contamination is removed from the Luckey site, the length of time is assumed to be zero years. For Alternatives 7, 8, and 9, groundwater monitoring will continue for the duration of the remedy. This period ranges from 40 to 150 years.

5.1 ALTERNATIVE 1: NO ACTION (SOILS AND GROUNDWATER)

Alternative 1 leaves the Luckey site “as is” with no actions taken regarding access or land use controls beyond those already in place for other reasons. This alternative provides no additional protection to human health and the environment over current conditions. The no-action alternative is required under the NCP as a no-action baseline against which other alternatives can be compared.

Under this alternative, impacted soils would remain at their current locations. Since impacted soils would remain in place, their impact on groundwater would be unabated. Existing legal and administrative mechanisms (maintenance of lagoon covers) and physical mechanisms (site security fencing) would be left in place but not necessarily maintained. Environmental monitoring would not be performed. In addition, no restrictions on land use would be pursued. However, the site is assumed to operate in compliance with existing regulations that impose limitations on occupational exposures.

5.2 ALTERNATIVE 2: LIMITED ACTION (SOILS AND GROUNDWATER)

Alternative 2 relies on limited site improvements (erosion control and maintenance) and natural attenuation of impacted groundwater supplemented with land use controls to limit exposures to site contaminants in both soils and groundwater. Impacted soils would be left in place. No active remedial measures would be implemented for either soils or groundwater. The site is assumed to operate in compliance with existing regulations that impose limitations on occupational exposures. A 1,000 year O&M period would be implemented. Prior to implementation of Alternative 2, a management plan detailing limited site improvements, location and frequency of groundwater monitoring, and supplemental land use controls would be developed. Components of this alternative include:

- Management plan
- Limited site improvements
- Natural Attenuation
- Land use controls
- Environmental Monitoring.

A long-term management plan would be developed to address maintenance activities, monitoring requirements, and land use controls. The plan would address any existing land use controls (i.e., continued maintenance of the current status of the lagoons located on site). The plan also would include provisions addressing the process by which property owners can contact the federal government agency responsible for long-term control of impacted areas as well as provide for periodic reviews. A more detailed discussion of the land use controls (administrative, legal, and physical mechanisms) would be developed as part of the long-term management plan including notification requirements for changes in land use. Coordination of limited site improvement and environmental monitoring activities at the site with the land owner and/or tenants would be necessary to minimize disruption of their activities. Pursuant to CERCLA, a site review would be conducted every five years, as contaminants would remain on site above levels allowing unlimited use and unrestricted exposure. Five-year reviews permit evaluation of the effectiveness of land use controls as well as data obtained from ongoing monitoring to assess the presence and behavior of remaining contaminants. Continued site surveillance would ensure any land use changes or disturbances of contaminated areas are identified.

Limited site improvements would be implemented to address erosion control and reduce direct exposure. Exposed areas of impacted soils in the northeast corner of the site and other areas devoid of vegetation could be given limited soil amendments. This could include being planted with grass or otherwise covered to limit the mobility and potential spread of contaminants from the soil surface. These measures also would limit the generation of dust and the potential for the airborne spread of contaminants from the site. An inspection of the site would be implemented under the long-term management plan to identify areas to be repaired as a result of natural or anthropogenic activities. Soil would be spread and reseeded would occur as determined necessary to reduce direct contact and maintain erosion control.

Natural attenuation of groundwater relies upon naturally occurring processes to address impacted groundwater. The primary attenuation processes affecting beryllium, lead, and uranium include sorption, diffusion, and mechanical dispersion. Natural processes, such as chemical reactions, precipitation, and dissolution also may reduce contaminant mobility, concentration, or bioavailability to some extent at the Lucky site. These attenuation processes reduce contaminant concentrations as they migrate vertically and horizontally through the groundwater flow system. Contaminant characteristics and site-specific lithology combined with the slow rate of groundwater flow generally limit the extent and magnitude of contamination above cleanup goals to localized areas. In addition, SESOIL and RESRAD modeling results indicate AEC-related constituents do not leach through the clay-rich tills at concentrations exceeding their respective risk- or ARAR-based cleanup goals using realistic distribution coefficients, or K_d values (Appendix 6A).

Land use controls are implemented in this alternative to limit exposure of human receptors to site contaminants in both soils and groundwater. These controls would include physical security such as fencing and signs, and would include measures to notify future property owners and restrict land use changes over the long-term, such as governmental controls, proprietary controls, and informational devices. These controls would be imposed anywhere soils are left in place above the established cleanup goals. This would include the lagoons, the northeast corner of the site, and adjacent property where material is above established cleanup goals. Fencing and signs would be inspected and replaced as necessary. Existing land use controls addressing Lagoons A, B, and C would be carried forward. Land use controls also would be used to limit exposure to groundwater, as long as monitoring indicates contamination in groundwater is above cleanup goals. These include governmental controls, such as zoning, proprietary measures such as easements, and informational controls such as educational or notice measures (e.g. deed notices).

Environmental monitoring would be conducted to assess contamination migrating from the site and potential for exposures. Monitoring would include soil, surface water, sediment, groundwater, and air media. Monitoring would be continued for 1,000 years to ensure human activities are limited at or near contaminated facilities, human health and the environment are protected, and response actions continue to be effective.

5.3 ALTERNATIVE 3: CONSOLIDATION AND CAPPING (SOILS)

Under Alternative 3, all impacted soils above unrestricted land use cleanup goals would be consolidated to an area approximately three to five (3 to 5) acres. One area under consideration is located in the northeastern portion of the site. Material exceeding unrestricted land use cleanup guidelines would be excavated and moved. After consolidation, a cap would be constructed to minimize migration of contaminants in the soil to groundwater. This option would require land use controls to limit use of and access to the capped portion of the site, as well as environmental monitoring to detect breaching of the cap and contaminant migration. The remainder of the site would be available for unrestricted land use. This alternative also would require close coordination of remediation and monitoring activities with the land owner(s) and/or tenants to minimize the health and safety risks to on-site personnel and to minimize

disruption to their activities consistent with a safe and effective remediation. Coordination would include obtaining access to areas north and east of the current fence line, since impacted soils lie outside the facility fence. Remedial action would require approximately two (2) years to complete and would include a 1,000 year O&M period. A conceptualization of this alternative is presented in Figure 5.1. Components of this alternative include:

- Remedial Design Plan
- Consolidation
- Capping
- Confirmatory sampling
- Site restoration
- Management plan
- Land use controls
- Environmental Monitoring.

Remedial design plan. Initiation of remediation would be preceded by the development of a remedial design plan. Specific design issues for the consolidation location and cap would be studied. The consolidation location will consider impacts to re-use of the remainder of the site as well as impacts to groundwater. The preferred location will be evaluated to determine overall effectiveness, adequate size of area, potential impacts on wetlands, stability of the terrain, hydrogeologic considerations, adequate buffers, and demographic considerations. Site data, such as topographic, geologic, hydrogeologic, utility and land use maps may be needed. One possible location is the northeastern corner of the site due to its distance from existing site operations, absence of structures, and a large volume of impacted soils currently in place. The cap would be designed to minimize exposures, surface water infiltration, and required maintenance. The remedial design plan would detail excavation activities including the sequence of consolidation and construction of the cap. Short term land use controls will be necessary during the active construction period to ensure a safe remediation.

Consolidation. Impacted soils would be excavated and transported to the selected consolidation location. Once a preferred location is selected, it must be prepared by amending and compacting subsurface soils to provide a solid foundation. The adjacent site areas will be re-graded to promote the conveyance of water away from the capped area. Assuming a total ex situ soil volume of 88,000 cy, the consolidation location is estimated to cover three to five (3 to 5) acres with a fifteen to twenty-five (15 to 25) ft elevation above existing grade. The volume of soils to be excavated is anticipated to be approximately 75,000 cy (ex situ). The remaining 13,000 cy would remain in place at the consolidation location. Impacted areas can be seen in Figure 5.1.

Standard construction equipment such as excavators, bulldozers, roller compactors, and dump trucks would be used to remove contaminated material and construct the consolidation location. Excavation would be guided using a Laser Induced Breakdown Spectroscopy (LIBS) probe to detect beryllium; x-ray fluorescence to detect lead; hand held radiation meters to detect radionuclides; and a limited quantity of analytical samples. Excavated soil would be transported directly to the consolidation area, dumped, and spread. Erosion control materials such as silt fences and straw bales would be installed to minimize erosion during excavation and consolidation activities. Impacted soils would be kept moist or covered with tarps to minimize dust generation. The safety of remediation workers, on-site employees, and the general public would be addressed in a site-specific health and safety plan. The health and safety plan would address potential exposures and monitoring requirements to ensure protection. Safety measures may include: the installation of filters on building air intakes to prevent contamination being drawn into the heating, ventilation, and air conditioning (HVAC) systems of on-site buildings.

Capping. Capping is a well-established remediation technology. A 13-ft multi-layer cover (cap) design for a low level radiological repository was selected for costing purposes. The standard design for cover systems ranges from eight to 18 ft. An eight-ft thick cover system would only be applicable in arid areas. The cover system should effectively protect human health and the environment through waste isolation for up to 1,000 years, to the extent reasonably achievable, and, in any case, for at least 200 years. This cap includes layers of clay, synthetic liners, sand, topsoil, and a vegetation layer. Most materials for the cap would be available from local off-site sources. The synthetic liner may not be available from a local vendor but would be installed by a specialty contractor. The cap would be designed and constructed to minimize the migration of liquids through the cover materials; promote drainage and minimize erosion or abrasion; reduce external gamma radiation and radon emissions; accommodate settling and subsidence to maintain the integrity of the cover; resist intrusion of humans, plants, and animals; and function with minimal maintenance. The overall effectiveness of the final cap in reducing infiltration and subsequent leaching is the key to performance and can be increased by using multiple layers.

Confirmatory sampling would be conducted after excavation of each area. This sampling would confirm unrestricted land use cleanup goals for inorganic and radiological constituents have been achieved. Areas that have been successfully remediated would be free for uses similar to other land uses in the area. Final status surveys would be performed using the MARSSIM statistical sampling approach to address radiological constituents. A statistical approach also would be developed for addressing inorganic constituents. The two approaches will be integrated into a comprehensive confirmatory sampling plan.

Site Restoration. Areas of the site where soil has been excavated will be backfilled with clean soil (un-impacted soil excavated from the site and off-site fill, approximately 20 acres) and re-vegetated. Fill would be tested prior to placement to ensure that it meets criteria as established in the remedial design plan. Confirmatory sampling and site restoration may progress area by area to prevent the occurrence of large denuded areas to minimize erosion and dust generation.

A *long-term management plan* would be developed to address notification requirements for property owners for changes in land use, as well as future monitoring and maintenance requirements. The plan would include provisions addressing the process by which property owners can contact the federal government agency responsible for long-term control of impacted areas, as well as provide for periodic reviews, maintenance, and monitoring. A more detailed discussion of the land use controls (administrative, legal, and physical mechanisms) would be developed as part of the long-term management plan including notification requirements for changes in land use. Pursuant to CERCLA, a site review would be conducted every five years, as contaminants would remain on site above levels allowing unlimited use and unrestricted exposure. Five-year reviews permit evaluation of the effectiveness of land use controls as well as data obtained from ongoing monitoring to assess the presence and behavior of remaining contaminants. Continued site surveillance would ensure any land use changes or disturbances of contaminated areas are identified.

Land use controls would be used to restrict land use in the vicinity of the consolidation location, where concentrations of contaminants exceed cleanup goals and land use controls are needed to assure protectiveness. Land use controls would include continuing the existing and installing new access restrictions; maintaining cover materials including grass and asphalt; maintaining fencing and signs; periodic inspection of the site to determine any changes in land use; land use restrictions to prohibit changes in land and groundwater uses or construction in impacted soils (i.e., the capped portion of the site). These controls also would include measures to restrict land use changes over the long-term, such as governmental controls, proprietary controls, and informational devices.

Environmental monitoring would be conducted to assess contaminant migration and would include soil, surface water, sediment, and groundwater. Since contamination would remain on site, for purposes of this FS, long-term monitoring is assumed to continue for 1,000 years.

Groundwater options are addressed in Alternatives 7, 8, and 9. An effective consolidation and capping design, or cover system, would address impacts to groundwater (leaching through and direct contact with impacted soils). Both natural attenuation and active remediation (Alternatives 7, 8, and 9) would be options to reduce contaminant concentrations in groundwater below cleanup goals.

5.4 ALTERNATIVE 4: EXCAVATION OF SOILS AND OFF-SITE DISPOSAL (SOILS) ~ INDUSTRIAL LAND USE

Alternative 4 consists of excavation of soils impacted above industrial land use cleanup goals and subsequent off-site disposal. The removal of impacted soils would address further impacts to groundwater via leaching and/or direct contact. Materials within the trenches and the former lagoons would be excavated to eliminate potential for direct contact with groundwater. This alternative also would require close coordination of remediation and monitoring activities with the land owner(s) and/or tenants. This coordination aims to minimize health and safety risks to on-site personnel and to minimize disruption to their activities consistent with a safe and effective remediation. This remedial action would require approximately two (1.7) years to complete and would include a 1,000 year O&M period. Components of this alternative include:

- Remedial Design Plan
- Excavation
- Transportation
- Off-site disposal
- Confirmatory sampling
- Site restoration
- Management plan
- Land use controls
- Environmental Monitoring.

Remedial design plan. Prior to the initiation of remedial action a remedial design plan would be developed. This plan would detail site preparation activities, the extent of the excavation, implementation and sequence of construction activities, decontamination, and segregation, transportation, and disposal of various waste streams. Short term land use controls will be necessary during the active construction period to ensure a safe remediation.

Excavation. Impacted soils would be excavated and transported to a soils staging area for loading into intermodal containers or trucks. Impacted areas are depicted in Figure 5.2 and specifically include the trenches located in the northeast corner of the site. The total disposal volume (i.e., ex situ) is estimated to be 47,600 cy (Table 3.5). Standard construction equipment such as excavators, bulldozers, front-end loaders, and scrapers would be used to remove contaminated material. Excavation would be guided using a LIBS probe to detect beryllium; x-ray fluorescence to detect lead; hand held radiation meters to detect radionuclides; and a limited quantity of analytical samples. Oversize debris would be crushed or otherwise processed to meet disposal facility requirements. Movement of impacted soils would be performed using dump trucks and conventional construction equipment. Erosion control materials such as silt fences and straw bales would be installed to minimize erosion. Impacted soils would be kept moist or covered with tarps to minimize dust generation. Excavation would take place in stages to limit impacts to current site production activities. The safety of remediation workers, on-site employees, and the general public would be addressed in a site-specific health and safety plan. The

health and safety plan would address potential exposures and monitoring requirements to ensure protection. Safety measures may include the installation of filters on building air intakes to prevent contamination being drawn into the HVAC systems of on-site buildings.

Transportation. Impacted soils would be hauled to a licensed or permitted disposal facility by truck and railcar. Intermodal containers would be transported via truck to an off-site staging area where they would be transferred from trucks to railcars. The railcars would transport the contaminated materials directly to the disposal facility where they would be offloaded and placed in a waste cell. The appropriate bill-of-lading would accompany the waste shipment. Only regulated and licensed transporters and vehicles would be used. The transport vehicles will travel pre-designated routes and an emergency response plan will be developed in the event of a vehicle accident. It is currently estimated ten to twelve trucks would travel to and from the off-site staging area each day.

Transportation activities would be performed in accordance with a site-specific Transportation and Emergency Response Plan (TERP) developed in the detailed design phase of the project upon selection of an alternative. The TERP would evaluate the types and number of vehicles to be used; the safest transportation routes, which includes minimizing the use of roads with high traffic volumes, public facilities, or secondary roads not designed for trucks; the closest available rail transfer facilities; and emergency response procedures for responding to a vehicle accident. A preliminary assessment of these transportation options are presented in Appendix 4B.

Off-site Disposal. Impacted soils would be disposed at a facility licensed or permitted to accept the characterized waste stream. The selection of an appropriate facility will consider the types of wastes, location, transportation options, and cost. Different waste streams with different constituents and/or characteristics may be generated and it may be possible to reduce disposal costs by utilizing specific disposal facilities for different waste streams.

Confirmatory sampling would be conducted after excavation of each area. This sampling would confirm industrial land use cleanup goals have been achieved. Areas successfully remediated would be available for industrial land use only. Final status surveys would be performed using the MARSSIM statistical sampling approach to address radiological constituents. A statistical approach also would be developed for addressing inorganic constituents. The two approaches will be integrated into a comprehensive confirmatory sampling plan.

Site Restoration. Areas of the site where soil has been excavated will be backfilled with clean soil (un-impacted soil excavated from the site and off-site fill) and re-vegetated. Fill would be tested prior to placement to ensure it meets criteria as established in the design. Confirmatory sampling and site restoration can progress area by area to prevent the occurrence of large denuded areas to minimize erosion and dust generation.

A *long-term management plan* would be developed to address notification requirements for property owners for changes in land use. The plan would include provisions addressing the process by which property owners can contact the federal government agency responsible for long-term control of impacted areas as well as provide for periodic reviews. Pursuant to CERCLA, a site review would be conducted every five years, as contaminants would remain on site above levels allowing unlimited use and unrestricted exposure. Five-year reviews permit evaluation of the effectiveness of land use controls. Continued site surveillance would ensure any land use changes are identified.

Land use controls would be installed to restrict land use, since soils would remain on site above concentrations that would allow for unrestricted land. Land use controls also would be utilized to assure protectiveness. Land use controls would include continuing the existing and installing new access

restrictions; maintaining cover materials including grass and asphalt; maintaining fencing and signs; periodic inspection of the site to determine any changes in land use; and land use restrictions to prohibit changes in land use. These controls would include measures such as governmental controls, proprietary controls and informational devices.

Environmental monitoring would be conducted to assess potential off-site contaminant migration and would include soil, surface water, and sediment. Since contamination would remain on site, for purposes of this FS, long-term monitoring is assumed to continue for 1,000 years.

Groundwater actions are covered under Alternatives 7, 8, and 9. Under this alternative, some impacted soils, with the potential to come in contact with groundwater, would be excavated, thereby removing a source of contamination to groundwater. Both natural attenuation and active remediation (Alternatives 7, 8, and 9) would be options to reduce contaminant concentrations in groundwater below cleanup goals.

5.5 ALTERNATIVE 5: EXCAVATION OF SOILS AND OFF-SITE DISPOSAL (SOILS) ~ UNRESTRICTED LAND USE

Alternative 5 consists of excavation of impacted soils above unrestricted land use cleanup goals and subsequent off-site disposal. The removal of impacted soils would address further impacts to groundwater via leaching and/or direct contact. All materials within the trenches and the former lagoons would be excavated to eliminate potential for direct contact with groundwater. This alternative also would require close coordination of remediation and monitoring activities with the land owner(s) and/or tenants to minimize health and safety risks to on-site personnel and to minimize disruption to their activities consistent with a safe and effective remediation. Coordination will include obtaining access to areas north and east of the current fence line since impacted soils lie outside the facility fence. This remedial action would require approximately three (2.9) years to complete and would not include an O&M period. Components of this alternative include:

- Remedial Design Plan
- Excavation
- Transportation
- Off-site disposal
- Confirmatory sampling
- Site restoration.

Remedial design plan. Prior to the initiation of remedial action a remedial design plan would be developed. This plan would detail site preparation activities, the extent of the excavation, implementation and sequence of construction activities, decontamination, and segregation, transportation, and disposal of various waste streams. Short term land use controls will be necessary during the active construction period to ensure a safe remediation.

Excavation. Impacted soils would be excavated and transported to a soils staging area for loading into intermodals or trucks. Impacted areas are depicted in Figure 5.3 and specifically include the lagoons and the contamination in the northeast corner of the site. It is estimated the total disposal volume (i.e., ex situ) will be 88,000 cy (Table 3.4). Standard construction equipment such as excavators, bulldozers, front-end loaders, and scrapers would be used to remove contaminated material. Excavation would be guided using a LIBS probe to detect beryllium; x-ray fluorescence to detect lead; hand held radiation meters to detect radionuclides; and a limited quantity of analytical samples. Oversize debris would be crushed or otherwise processed to meet disposal facility requirements. Movement of impacted soils would be performed using dump trucks and conventional construction equipment. Erosion control

materials such as silt fences and straw bales would be installed to minimize erosion. Impacted soils would be kept moist or covered with tarps to minimize dust generation. Excavation would take place in stages to limit impacts to current site production activities. The safety of remediation workers, on-site employees, and the general public would be addressed in a site-specific health and safety plan. The health and safety plan would address potential exposures and monitoring requirements to ensure protection. Safety measures may include the installation of filters on building air intakes to prevent contamination being drawn into the HVAC systems of on-site buildings.

Transportation. Impacted soils would be hauled to a licensed or permitted disposal facility by truck and railcar. A significant portion of the material (estimated at 64%, Appendix 3B) would be disposed within the State of Ohio as solid waste via truck. Trucks would be lined with polyethylene sheeting (inter-modal containers similarly lined also could be used) and covered with specially designed tarps or hard covers to prevent release of impacted soils. All trucks would be inspected prior to use and surveyed for contamination prior to leaving the site. The appropriate bill-of-lading (in accordance with Department of Transportation (DOT) regulations for shipment of contaminated materials on public roads) would accompany the waste shipment. Only regulated and licensed transporters and vehicles would be used. The transport vehicles will travel pre-designated routes and an emergency response plan will be developed in the event of a vehicle accident. It is currently estimated 10 to 12 trucks would travel to and from the off-site staging area and in-state disposal facility each day.

The remaining soil, primarily FUSRAP radioactive waste, would be shipped in intermodal containers and disposed at an out-of-state facility. Intermodal containers would be transported via truck to an off-site staging area where they would be transferred from trucks to railcars. The railcars would transport the contaminated materials directly to the disposal facility where they would be offloaded and placed in a waste cell. The appropriate bill-of-lading would accompany the waste shipment. Again, only regulated and licensed transporters and vehicles would be used.

Transportation activities would be performed in accordance with a site-specific TERP developed in the detailed design phase of the project upon selection of an alternative. The TERP would evaluate the types and number of vehicles to be used; the safest transportation routes which includes minimizing the use of roads with high traffic volumes, public facilities, or secondary roads not designed for trucks; the closest available rail transfer facilities; and emergency response procedures for responding to a vehicle accident. A preliminary assessment of these transportation options are presented in Appendix 4B.

Off-site Disposal. Impacted soils would be disposed at a facility licensed or permitted to accept the characterized waste stream. The selection of an appropriate facility will consider the types of wastes, location, transportation options, and cost. Different waste streams with different constituents and/or characteristics may be generated and it may be possible to reduce disposal costs by utilizing specific disposal facilities for different waste streams.

Confirmatory sampling would be conducted after excavation of each area. This sampling would confirm unrestricted land use cleanup goals for inorganic and radiological constituents have been achieved. Areas successfully remediated would be free for unrestricted land use. Final status surveys would be performed using the MARSSIM statistical sampling approach to address radiological constituents. A statistical approach also would be developed for addressing inorganic constituents. The two approaches will be integrated into a comprehensive confirmatory sampling plan.

Site Restoration. Areas of the site where soil has been excavated will be backfilled with clean soil (un-impacted soil excavated from the site and off-site fill) and re-vegetated. Fill would be tested prior to placement to ensure it meets criteria as established in the design. Confirmatory sampling and site

restoration can progress area by area to prevent the occurrence of large denuded areas to minimize erosion and dust generation.

Groundwater actions are covered under Alternatives 7, 8, and 9. Under this alternative, impacted soils would be excavated, thereby removing the source of contamination to groundwater. Both natural attenuation and active remediation (Alternatives 7, 8, and 9) would be options to reduce contaminant concentrations in groundwater below cleanup goals.

5.6 ALTERNATIVE 6: EXCAVATION OF SOILS, TREATMENT, AND OFF-SITE DISPOSAL (SOILS) ~ UNRESTRICTED LAND USE

Alternative 6 consists of excavation of impacted soils above unrestricted land use cleanup goals, soil treatment, and subsequent off-site disposal. The removal of impacted soils would address further impacts to groundwater via leaching and/or direct contact. This alternative is similar to Alternative 5; however, Alternative 6 includes treatment of excavated soils to reduce the volume of material requiring disposal. As with Alternative 5, all materials from within the trenches and the former lagoons would be excavated to eliminate potential for direct contact with groundwater. Only radiological constituents in impacted soils are currently expected to be treatable by the selected technology. The remaining impacted soils would be excavated and transported, as in Alternative 5. This alternative also would also require close coordination of remediation, treatment and monitoring activities with the land owner(s) and/or tenants. This will serve to minimize the health and safety risks to on-site personnel and to minimize disruption to their activities consistent with a safe and effective remediation. Coordination will include obtaining access to areas north and east of the current fence line since impacted soils lie outside the facility fence. Remedial action would require three (3) years to complete and would not include an O&M period. In order to determine the effectiveness of the soil treatment process, a treatability study will be performed. Components of this alternative include:

- Select soil treatment technology
- Remedial Design Plan
- Excavation
- Conduct treatment
- Transportation
- Off-site disposal of impacted soils and residual waste
- Confirmatory sampling
- Site restoration.

Select soil treatment technology. Soil treatment is an additional feature in Alternative 6, not seen in Alternative 5. Soil washing has been selected as the treatment technology and is the basis for the cost of this alternative. Treatability studies would be performed to evaluate and confirm the effectiveness, implementability, and cost of various soil washing options. Materials would be processed using a variety of techniques to remove contamination exceeding the designated standards. The fact that soil washing has been selected here does not preclude the addition or use of any viable technologies that might become available in the future, but provides a representative treatment scenario for the purpose of comparison to the other alternatives.

Remedial design plan. Utilizing the results of the treatability study, a remedial design plan would be developed prior to the initiation of remedial action. This plan would detail site preparation activities, the extent of the excavation, implementation and sequence of construction and soil treatment activities, decontamination, and segregation, transportation, and disposal of various waste streams. Short term land use controls will be necessary during the active construction period to ensure a safe remediation.

Excavation. Impacted soils would be excavated, loaded into trucks, and transported to a staging area for treatment. Impacted areas are depicted in Figure 5.3 and specifically include the lagoons and the contamination in the northeast corner of the site. It is estimated the total excavation volume (ex situ) will be 88,000 cy (Table 3.4). Standard construction equipment, such as excavators, bulldozers, front end loaders, and scrapers would be used to remove contaminated material. Excavation would be guided using a LIBS probe to detect beryllium; x-ray fluorescence to detect lead; hand held radiation meters to detect radionuclides; and a limited quantity of analytical samples. Oversize debris would be crushed or otherwise processed to meet disposal facility requirements. Movement of impacted soils would be performed using dump trucks and conventional construction equipment. Erosion control materials, such as silt fences and straw bales would be installed to minimize erosion. Impacted soils would be kept moist or covered with tarps to minimize dust generation. Excavation would take place in stages to limit impacts to current site production activities. Following treatment, impacted soils would be loaded into intermodals, trucked to a nearby rail spur, and shipped to an off-site disposal facility. The safety of remediation workers, on-site employees, and the general public would be addressed in a site-specific health and safety plan. The health and safety plan would address potential exposures and monitoring requirements to ensure protection. Safety measures may include the installation of filters on building air intakes to prevent contamination being drawn into the HVAC systems of on-site buildings. Short term land use controls will be necessary during the active construction and treatment period to ensure a safe remediation.

Conduct treatment. The soil washing process is expected to concentrate the radiological contaminants in the small particle size fraction. Commercial treatment equipment is available for this technology, to be either built on site or brought to the site assembled. The treatment facility itself can be a transportable system, mounted on trailers, and need not be a permanent installation. The specific design, throughput, and operational capability of the process must be defined and is addressed further in the detailed analysis of alternatives. It is estimated half (14,500 cy) of the excavated and treated soil (29,000 cy) would be available for backfill (assuming 50% effectiveness of treatment process). Pilot and full-scale operations with similar equipment have been conducted elsewhere in the U.S. at capacities ranging up to 100 tons/hour.

Developing physical treatment capabilities on site would begin by establishing a specific location at which to install the treatment process. Utilities and water service must be available to operate the soil washing equipment. Further preparation of the site would involve building a concrete pad to hold the treatment equipment if needed.

Soils must be transported from the area of excavation to the treatment site. In the first treatment step, excavated soils are put through a coarse separation-sizing screen to remove any debris or large objects. The remaining soil enters the separation system. During processing, the soils are agitated vigorously to break up colloidal material and to ensure soil particles are suspended to the degree necessary for effective treatment. Particle separation may be accomplished by various means including wet sieving, hydrocyclones, density separation, and froth flotation.

The soil washing system separates the soil into two size ranges. The larger, less radioactively contaminated particles (cleaned to acceptable levels), are removed for disposal as industrial waste or for use as backfill. The smaller particles are carried with the wash water to a clarifier, where surfactants or filter aids may be added to remove the particles from the wash water. Radioactively contaminated fine soil particles are removed from the clarifier and dewatered, typically in filter presses or similar devices. The dried concentrated soils can be loaded for disposal at an off-site facility. The wash water is filtered as required and reused. Wash water also would be sampled and disposed as appropriate.

Transportation. Impacted soils would be hauled to a disposal facility by truck and railcar. A significant portion of the material (estimated at 64%, Appendix 3B) would be disposed within the State of Ohio as solid waste via truck. Trucks would be lined with polyethylene sheeting (inter-modal containers similarly lined also could be used) and covered with specially designed tarps or hard covers to prevent release of impacted soils. All trucks would be inspected prior to use and surveyed for contamination prior to leaving the site. The appropriate bill-of-lading (in accordance with DOT regulations for shipment of contaminated materials on public roads) would accompany the waste shipment. Only regulated and licensed transporters and vehicles would be used. The transport vehicles will travel pre-designated routes and an emergency response plan will be developed in the event of a vehicle accident. It is currently estimated 10 to 12 trucks would travel to and from the off-site staging area and in-state disposal facility each day.

The treatment residuals (i.e., FUSRAP radioactive waste), which would be disposed out-of-state, would be shipped in intermodal containers. The intermodal containers would be transported to an off-site staging area where they would be transferred from trucks to railcars. The railcars would transport the contaminated materials directly to the disposal facility where they would be offloaded and placed in a waste cell. The appropriate bill-of-lading would accompany the waste shipment. Again, only regulated and licensed transporters and vehicles would be used.

Transportation activities would be performed in accordance with a site-specific TERP developed in the detailed design phase of the project once an alternative is selected. The TERP would evaluate the types and number of vehicles to be used; the safest transportation routes which includes minimizing the use of roads with high traffic volumes, public facilities, or secondary roads not designed for trucks; the closest available rail transfer facilities; and emergency response procedures for responding to a vehicle accident.

Off-site disposal. Impacted soils would be disposed at a facility licensed or permitted to accept the characterized waste stream. The selection of an appropriate facility will consider the types of wastes, location, transportation options, and cost. Different waste streams with different constituents and/or characteristics may be generated and it may be possible to reduce disposal costs by utilizing specific disposal facilities for different waste streams.

If the treatment technology is effective, the volume of soil requiring disposal will be reduced. The extent of the reduction will depend upon the technology chosen, its effectiveness, and implementation in the field. In addition, the use of the treatment technology may change the nature and the characteristics of the wastes generated. This may change which facilities are able to accept the waste.

Confirmatory sampling would be conducted after excavation of each area. This sampling would confirm unrestricted land use cleanup goals for inorganic and radiological constituents have been achieved. Areas successfully remediated would be free for unrestricted use. Final status surveys would be performed using the MARSSIM statistical sampling approach to address radiological constituents. A statistical approach also would be developed for addressing inorganic constituents. The two approaches will be integrated into a comprehensive confirmatory sampling plan.

Site restoration. Areas of the site where soil has been excavated will be backfilled with clean soil (un-impacted soils excavated from the site and off-site fill) and re-vegetated. Fill would be tested prior to placement to ensure it meets criteria as established in the design. Confirmatory sampling and site restoration can progress area by area to prevent large areas of soil from being exposed at any one time in order to minimize erosion and dust generation. Treated soils that meet cleanup goals also could be used for subsurface backfill. Once treatment is complete, the treatment equipment will be decontaminated, dismantled, and removed and the treatment area restored.

Groundwater actions are covered under Alternatives 7, 8, and 9. Under this alternative, impacted soils would be excavated, thereby removing the source of contamination to groundwater. Both natural attenuation and active remediation (Alternatives 7, 8, and 9) would be options to reduce contaminant concentrations in groundwater below cleanup goals.

5.7 ALTERNATIVE 7: MONITORED NATURAL ATTENUATION (GROUNDWATER) ~ UNRESTRICTED LAND USE

Alternative 7 relies on MNA to address impacted groundwater once impacted soils are remediated. The primary attenuation processes affecting beryllium, lead, and uranium in groundwater include sorption, diffusion, and mechanical dispersion. Alternative 7 would be implemented in conjunction with Alternative 3, 4, 5, or 6 in accordance with EPA guidance (1999a).

Under this alternative, monitoring wells would be installed to monitor concentrations in groundwater. Monitoring wells currently are proposed to be located at the same locations as existing wells based on observed constituent concentration trends. Replacement wells may be necessary to maintain viability during the potentially long timeframe associated with MNA as well as the possibility of damage or removal of wells during implementation of the soils alternative. Coordination with the land owner(s) and/or tenants will be required both during the installation of wells and during periodic sampling events. Coordination could include obtaining right-of-entry and easements for properties outside the current fence to perform monitoring.

MNA would require an approximate 150 year O&M period after impacted soils have been addressed. This time period is based upon modeling results of beryllium concentrations in sands and gravels near the northern property boundary. Beryllium concentrations in the carbonate bedrock are predicted to drop below cleanup goals within 40 years. Lead and uranium concentrations achieve cleanup goals within 3.5 and 30 years, respectively. The beryllium concentrations in the sands and gravels are expected to drop significantly after the source is removed based upon the assumption that periodic wetting of source materials results in the observed groundwater contamination. This assumption is based upon modeling results (which indicate that beryllium leaching through soil to groundwater is not a likely source) and observations of elevated beryllium concentrations at seasonally high groundwater levels. The magnitude of the drop in beryllium concentrations after source removal is uncertain. Conservative source terms representing the existing beryllium concentration in groundwater were used in fate and transport modeling. Modeling results predict a reduction in beryllium concentrations to cleanup levels in 150 years for the sands and gravels (40 years for attainment of beryllium cleanup levels in the bedrock) after source removal. For cost estimating purposes, an O&M time period of 150 years (after impacted soils were addressed) was used. Components of this alternative include:

- Remedial Design Plan
- Monitored Natural Attenuation
- Confirmatory sampling
- Management plan
- Land use controls.

Remedial design plan. Prior to implementing Alternative 7, a remedial design plan will be completed. This plan will evaluate and detail the number and location of monitoring wells, the constituents to be monitored, and the criteria to determine if MNA is working. The safety of remediation workers, on-site employees, and the general public would be addressed in a site-specific health and safety plan. The health and safety plan would address potential exposures and monitoring requirements to ensure protection.

Monitored natural attenuation. Attenuation processes affecting beryllium, lead, and uranium include sorption, diffusion, and mechanical dispersion. Natural processes such as chemical reactions, precipitation, and dissolution also may reduce contaminant mobility, concentration, or bioavailability to some extent at the Luckey site. Biodegradation and radioactive decay are not expected to be significant in the attenuation of beryllium, lead, and uranium in groundwater.

Sorption and diffusion are the primary attenuation processes in the clay-rich till, where groundwater moves slowly. Contaminants will diffuse into the clay-rich till, which provides abundant surface area for the sorption of metals from the groundwater. Within sands and gravels, sorption and mechanical dispersion are the primary attenuation mechanisms. Sands and gravels at the Luckey site typically contain a significant percentage of silts and clays thus increasing the sorption capacity of the sands and gravels as groundwater migrates through them. Groundwater also is moving at a higher velocity through the sands and gravels, resulting in more mixing (mechanical dispersion) relative to groundwater within the clay-rich till. Within the carbonate bedrock, mechanical dispersion is expected to be the primary attenuation mechanism affecting contaminant concentrations in the groundwater. Any clay-rich till within fractures and joints in the bedrock will act to increase its sorption capacity.

Groundwater in various zones (i.e., clay-rich till, sands and gravels, and bedrock) will be monitored in a network of monitoring wells until contaminant concentrations drop below respective cleanup goals. Twelve monitoring wells were assumed for cost estimating purposes. Figure 5.4 illustrates proposed groundwater monitoring locations. These locations are based on observed current conditions and predicted potential future migration pathways. Five wells would be located along the northern boundary. One is north of the trenches in the northeast corner, where low concentrations of the AEC-related constituents have been detected. The remaining four wells are in the area where beryllium has been consistently observed in groundwater. Two wells are located near the West Production Well, PW(W), to monitor beryllium. One well is proposed at each of the locations where lead and uranium have been detected (MW-21(I) and MW-24(S)). The three remaining wells are located to monitor future migration pathways and include continued monitoring of the East Production Well, PW(E), and two locations in the farm field north of the site.

Monitoring will be conducted to evaluate the remedy effectiveness and to ensure protection of human health and the environment. This monitoring program will be used to demonstrate that natural attenuation is occurring according to expectations. As indicated by EPA (1999a) the monitoring program will be designed to do the following:

- Demonstrate natural attenuation is occurring according to expectations
- Detect changes in environmental conditions that may affect attenuation rates
- Identify any potentially toxic transformation products
- Verify contamination is not expanding laterally, vertically, or down-gradient
- Verify no unacceptable impact to down-gradient receptors
- Detect new releases of contaminants
- Demonstrate efficacy of land use controls put in place to protect potential receptors
- Verify attainment of RAOs.

After a period of five to 10 years, if monitoring demonstrates changes to environmental conditions or the attenuation process is not proceeding as expected, then decisions regarding what actions are necessary will be made at that time based on the data and information gathered during the monitoring program.

Confirmatory sampling would be conducted for a period of one to three years after MNA indicates contaminant concentrations in groundwater have attenuated below cleanup goals. This sampling

would confirm cleanup goals for inorganic and radiological constituents in groundwater have been achieved.

A long-term management plan would be developed to address monitoring requirements and land use controls. The plan also would include provisions addressing the process by which property owners can contact the federal government agency responsible for long-term control of impacted areas as well as provide for periodic reviews. A more detailed discussion of the land use controls (administrative, legal, and physical mechanisms) would be developed as part of the long-term management plan including notification requirements for changes in land use. Pursuant to CERCLA, a site review would be conducted every five years, until contaminants in groundwater attenuate to levels allowing unlimited use and unrestricted exposure. Five-year reviews permit evaluation of the effectiveness of land use controls, as well as data obtained from ongoing monitoring to assess the presence and behavior of remaining contaminants. Continued site surveillance would ensure any land use changes or disturbances of contaminated areas are identified.

Land use controls would be used to supplement MNA as long as monitoring indicates contamination in groundwater is above cleanup goals. Land use controls would include periodic inspection of the site to determine any changes in land use and land use restrictions to prohibit changes in groundwater use. Land use controls considered to supplement MNA are governmental controls, such as zoning, proprietary measures, and informational devices.

5.8 ALTERNATIVE 8: ACTIVE GROUNDWATER TREATMENT – EX SITU (GROUNDWATER) ~ UNRESTRICTED LAND USE

Alternative 8 relies on the use of wells to extract impacted groundwater. The extraction wells would be completed across the interface between bedrock and overburden to affect the targeted media (sands/gravel and upper bedrock), with the total depth of the wells between five and 10 feet in bedrock. The wells would target materials moving in the sands and gravels and in the upper bedrock. The wells would not target materials sorbed to the clay-rich tills due to the extremely long periods of time predicted for remediation via pump and treat. Once extracted, the contaminated groundwater would be piped to an on-site treatment facility, where contaminants would be removed by adsorption via solid media (activated carbon for lead and uranium and activated alumina for beryllium). Alternative 8 consists of a groundwater pump and treat system and would be implemented in conjunction with Alternative 3, 4, 5, or 6 (i.e., source removal). Coordination with the land owner(s) and /or tenants will be required during the installation of wells, during periodic sampling events, and for the operation of the treatment facility. Coordination could include obtaining right-of-entry and easements for properties outside the current fence to perform extraction and/or monitoring. Assuming the contaminants are primarily located within the sands and gravels and the carbonate bedrock, active remedial measures would require 80 years to complete for beryllium and 10 years for uranium in the groundwater. Removal of lead from groundwater requires less than one year to complete using pump and treat. Time frames for groundwater cleanup via pump and treat could be substantially longer if significant contamination exists within the clay-rich till. Components of this alternative include:

- Remedial Design Plan
- System design and installation
- Active Pump and Treat
- Confirmatory sampling
- Management plan
- Land use controls.

Remedial design plan. Prior to the initiation of remediation, a remedial design plan will be completed. Contained within the plan will be details of where the extraction and monitoring wells are to be located, what constituents are to be analyzed at each monitoring well, and what the pumping rate of each extraction well is to be. Also included would be the details of the design of the treatment system. To accomplish this, a treatability study may be needed to determine the flow rates, size of the filter media, and the replacement intervals for the media. The safety of remediation workers, on-site employees, and the general public would be addressed in a site-specific health and safety plan. The health and safety plan would address potential exposures and monitoring requirements to ensure protection.

A *groundwater pump and treat system* would be designed and installed. The design would consist of the number and placement of groundwater extraction wells, as well as piping to the filtration system. The filtration system would be housed on site. Depending on the selected treatment system, a pilot study may be completed to determine the optimal configuration. For the cost estimate it was assumed six extraction wells would be installed and water would be treated by passing it through an adsorptive media (activated carbon for lead and uranium and activated alumina for beryllium). Treated water would either be discharged to surface water or to a POTW.

Figure 5.4 illustrates the proposed locations for groundwater extraction wells. The locations are general and indicate areas where extraction wells would be placed, rather than their exact locations (e.g. EX-1, EX-2, etc.). Two areas (EX-1 and EX-2) are located along the northern boundary of the site where beryllium has been consistently detected in groundwater above cleanup goals. Up to four extraction wells may be installed in these two areas. EX-3 represents the location of a single extraction well located near MW-24(S), where uranium and lead have commonly been detected above cleanup goals. Predictive modeling indicates lead detected at MW-21(I) (EX-4) and beryllium detected at the West Production Well (EX-5) naturally attenuate below their respective cleanup goals within five years, and therefore, most likely would not be addressed through the active groundwater pump and treat system.

Time frames for cleanup via pump and treat are longest at EX-1 where as long as 80 years may be required to remediate groundwater within the sands and gravels, and 25 years may be required for remediation of groundwater within the bedrock. At EX-2, time frames for groundwater remediation are 14 years for the sand and gravel and two years for bedrock. At EX-3, time frames for groundwater remediation are 10 years for the upper weathered bedrock. Groundwater monitoring also would be included as part of this alternative. The proposed monitoring network most likely would be very similar to the network proposed for MNA (Alternative 7, Figure 5.4). Groundwater monitoring would be performed annually for the first five years after source removal to confirm effectiveness.

Confirmatory sampling would be conducted for a period of three to five years after completion of active treatment. This sampling would confirm cleanup goals for inorganic and radiological constituents in groundwater have been achieved.

A *long-term management plan* would be developed to address monitoring requirements and land use controls. The plan also would include provisions addressing the process by which property owners can contact the federal government agency responsible for long-term control of impacted areas, as well as provide for periodic reviews. A more detailed discussion of the land use controls (administrative, legal, and physical mechanisms) would be developed as part of the long-term management plan including notification requirements for changes in land use. Pursuant to CERCLA, a site review would be conducted every five years until contaminants in groundwater are below levels allowing unlimited use and unrestricted exposure. Five-year reviews permit evaluation of the effectiveness of land use controls, as well as data obtained from ongoing monitoring to assess the presence and behavior of remaining contaminants. Continued site surveillance would ensure any land use changes or disturbances of contaminated areas are identified.

Land use controls would be used to supplement the active pump and treat remediation of groundwater as long as monitoring indicates contamination in groundwater is above cleanup goals. Land use controls would include continuing the existing and installing new access restrictions; maintaining fencing and signs; periodic inspection of the site to determine any changes in land use; and land use restrictions to prohibit changes in groundwater use. Land use controls considered to supplement active pump and treat are governmental controls such as zoning, proprietary measures such as easements, and informational devices.

5.9 ALTERNATIVE 9: ELECTROKINETICS (GROUNDWATER) ~ UNRESTRICTED LAND USE

Alternative 9 relies on electrokinetics, a treatment technology, to address impacted groundwater. This would be implemented in conjunction with Alternative 3, 4, 5, or 6 (i.e., source removal). Alternative 9 involves drilling a grid pattern of wells through the saturated clay-rich till to the fractured bedrock and installing electrodes. Each electrode is encased in a permeable membrane filled with an electrolyte solution. The electrodes are connected to a power source and metal contaminants in groundwater are driven to anodes, across the permeable membrane, ultimately being removed and disposed. Coordination with the land owner(s) and/or tenants will be required during the installation of wells and electrodes and during periodic sampling events. Coordination could include obtaining right-of-entry and easements for properties outside the current fence to perform electrokinetics and/or monitoring.

Electrokinetics would be utilized to remediate groundwater in the unconsolidated clay-rich till and sands and gravels overlying the carbonate bedrock at the site. Specifically, electrokinetics would potentially provide an effective means of remediating groundwater within the clay-rich till. AEC-related constituents consistently have been detected above cleanup goals in groundwater in the overburden in two areas at the Luckey site. Electrokinetics would be implemented to target these areas (Figure 5.5). Beryllium has been detected in the shallow groundwater at the northern boundary of the Luckey site. Uranium has been detected in the shallow groundwater just north of Lagoon B. Modeling results indicate the potential for constituents (beryllium and uranium) to remain above cleanup goals for long periods of time in the clay-rich till in these areas if left untreated.

Electrokinetics may not be effective at remediating contaminated groundwater within the carbonate bedrock, potentially requiring a monitoring program specific for groundwater within the carbonate bedrock after electrokinetic treatment is completed. In cases where the electrode wells are placed atop bedrock, the bedrock will largely deflect the electric field. At the Luckey site the top of the bedrock is fractured allowing the electric field to proceed along hydraulic flow paths between electrodes; however, the efficiency of inducing contaminant migration will be extremely limited. Components of this alternative include:

- Pilot study
- Remedial Design Plan
- Well installation
- Electrokinetic treatment
- Off-site disposal
- Site restoration
- Confirmatory sampling
- Land use controls.

Pilot studies. Pilot-scale field studies are required to evaluate the feasibility of the treatment process and to optimize electrode spacing and treatment times. Spacing is a critical determination in designing and operating electrokinetic systems because of the relationship between the treatment time and

subsequent power requirements necessary to achieve cleanup goals. Typical applications involve spacing the electrodes 3-m apart. Halving the spacing between electrodes results in tripling the number of electrodes while reducing the power requirement by two thirds. However, halving the treatment time for a fixed number of electrodes quadruples the power requirement to attain the same contaminant reduction or removal efficiency.

Pilot-scale field studies usually involve three rows of electrodes with between 3 and 9 electrodes per row. For purposes of cost estimating in Appendix 6B, it was assumed three rows of six electrodes each would be used in the pilot-scale study, spaced 3-m apart. It also was assumed for cost estimating purposes that the full-scale system would use 650 electrodes, also spaced 3-m apart. To reduce excessive capital and operating costs, it was further assumed beryllium-contaminated groundwater would be remediated first over a period of five years, after which the electrodes would be reused and installed in a grid pattern of 3-m spacing in the uranium-contaminated groundwater. It also was assumed the second phase of groundwater remediation would take ten years. Results of the pilot-scale field study, however, might affect the spacing and number of electrodes and/or the time necessary to complete each phase of the in situ treatment.

Remedial design plan. Based upon the results of the pilot study, a remedial design plan will be developed. The design plan will provide all of the details regarding electrode spacing, power requirements, maintenance requirements, and cleanup objectives, as well as sampling procedures for determining completion of the remedy. Groundwater monitoring would be performed during implementation (up to 15 years) and continue up to an additional 25 years to monitor contaminants in bedrock not addressed by implementation of electrokinetics. In addition, the plan will describe handling and disposal of the contaminated electrolyte solution, either as required during the remedy and/or following successful completion of the remedy. The remedial design plan would identify pertinent, short term land use controls to supplement implementation of electrokinetic remediation of groundwater as long as monitoring indicates contamination in groundwater is above cleanup goals. Land use controls considered to supplement electrokinetics are governmental controls, such as zoning, and proprietary measures, such as easements. The safety of remediation workers, on-site employees, and the general public would be addressed in a site-specific health and safety plan. The health and safety plan would address potential exposures and monitoring requirements to ensure protection.

Electrokinetic Treatment. Once electrolyte-encased electrodes are placed into groundwater, the electrodes are connected to a power source. Electrodes are wired in alternating rows of cathodes and anodes, with the outer ring of electrodes being wired as cathodes. In this way, metal contaminants are driven from the outer “fence line” of the treatment zone towards interior anodes where they are collected in the electrolytic solution surrounding each electrode.

A system of tanks and piping also is plumbed to the electrodes. Specifically, the electrolyte surrounding the cathodes contains acid, which must be replenished over the course of the treatment as it is consumed. (Acid prevents precipitate formation and fouling at the cathodes by neutralizing hydroxide that migrates to the cathodes.) In addition, chelating agents may be added to the cathode electrolyte and replenishment tanks to increase the solubility or mobility of the beryllium and uranium contaminants. For example, highly charged species of small atomic radii (such as beryllium compounds) have a high affinity to remain sorbed to soil in the subsurface. Chelating agents are used to keep target metal species suspended in solution and amenable to the electromotive driving potential. The chelating agents would result in preferential removal of targeted metal species and therefore, minimize the influence of other metal species in the flow system. The need for and appropriate concentration of chelating agents also would be determined during pilot-scale field studies.

Precipitate formation also can occur at the anodes if the electrolyte becomes saturated in metal salts. As a preventative measure, the electrolyte can be replaced periodically with fresh electrolyte. However, the low concentrations detected at the Luckey site make it unlikely the anode electrolyte will have to be removed before cleanup goals are reached. Periodic inspections and refilling of replenishment tanks, if needed, generally are performed on a weekly basis. In addition, the electric current is routinely monitored and can be adjusted remotely through a computer processor.

Off-site Disposal. Following attainment of cleanup goals in groundwater, the electrodes are removed from the well casings and the electrolyte is drained and disposed. The waste electrolyte collected from the anodes will contain the metal contaminants removed from the groundwater. Other metal species (such as lead) may co-migrate with the target contaminants; however, use of chelating agents may limit the amount of non-target metals that migrate to the anodes. An objective of the pilot-scale field study would be to optimize contaminant collection while minimizing collection of non-target compounds.

It is assumed approximately 325 anodes will generate approximately 800 gal of electrolyte (or approximately 15 fifty-five gal drums) per treated area. The approximate 325 cathodes will generate the same volume. The waste electrolyte generated from the cathodes is non-hazardous and can be disposed at a POTW or other wastewater treatment facility. In the case of beryllium, because it is not a hazardous waste, the electrolytic solution can be evaporated and the resulting salts can be disposed of in a Subtitle D landfill. For uranium-containing electrolyte, the solution will require treatment, such as solidification, before it can be disposed. Based on the average concentration of uranium in the groundwater, it is assumed 29,000 µg/L (26,000 µCi/L) of uranium will be contained in the electrolyte once the cleanup goal has been reached, corresponding to a total of 70 millicuries (mCi) for all of the uranium contaminated electrolyte.

Confirmatory sampling would be conducted for a period of three to five years after completion of electrokinetics to confirm cleanup goals for inorganic and radiological constituents in groundwater have been achieved.

Site Restoration. Following completion of the electrokinetic treatment, the polyvinyl chloride (PVC) casing is removed and the boreholes are backfilled with clean soil. The pH of the groundwater may locally be as low as 3 between the electrodes; however, the use of chelating agents may result in more modest pH effects.

A *long-term management plan* would be developed to address groundwater monitoring requirements and land use controls. The plan also would include provisions addressing the process by which property owners can contact the federal government agency responsible for long-term control of impacted areas as well as provide for periodic reviews. A more detailed discussion of the land use controls (administrative, legal, and physical mechanisms) would be developed as part of the long-term management plan including notification requirements for changes in land use. Pursuant to CERCLA, a site review would be conducted every five years until contaminants in groundwater are below levels allowing unlimited use and unrestricted exposure. Five-year reviews permit evaluation of the effectiveness of land use controls, as well as data obtained from ongoing monitoring to assess the presence and behavior of remaining contaminants. Continued site surveillance would ensure any land use changes or disturbances of contaminated areas are identified.

Land use controls would be used to supplement electrokinetics as long as monitoring indicates contamination in groundwater is above cleanup goals. Land use controls would include continuing the existing and installing new access restrictions; maintaining fencing and signs; periodic inspection of the site to determine any changes in land use; and land use restrictions to prohibit changes in groundwater

use. Additional land use controls considered to supplement electrokinetics are governmental controls, such as zoning, proprietary measures, such as easements.

Table 5.1. Summary of Remedial Alternatives

<p>Alternative 1 – No Action (Soils and Groundwater)</p> <p>This alternative would provide no further remedial action at the Luckey site and is included as a baseline against which other alternatives can be compared. Although land use controls are in place at the site, these would be left in place, but not necessarily maintained under this alternative. However, the site is assumed to operate in compliance with existing regulations that impose limitations on occupational exposures. Five-year reviews would be conducted in accordance with CERCLA 121(c).</p>
<p>Alternative 2 – Limited Action (Soils and Groundwater)</p> <p>This alternative would involve limited site improvements, maintenance, attenuation, periodic monitoring (i.e., soil, surface water, sediment, groundwater, and air) to detect any changes in the nature or extent of contamination at the site. Land use controls would include continuing the existing and installing new access restrictions; maintaining cover materials including grass and asphalt; maintaining fencing and signs; land use restrictions to prohibit changes in land and groundwater uses or construction in impacted soils; and periodic inspection of the site to determine any changes in land use. Remedial action would require zero years to complete and would include a 1,000 year O&M period. Five-year reviews would be conducted in accordance with CERCLA 121(c).</p>
<p>Alternative 3 – Consolidation and Capping (Soils)</p> <p>This alternative would involve consolidating impacted soils above unrestricted land use cleanup goals and covering with a multi-layer cap consisting of clay and synthetic liners to limit exposures and minimize contaminant migration. Impacted soils on-site and directly adjacent to the site would be consolidated at an on-site location. The capped portion of the site would be subjected to land use controls, while the remaining portion would be available for unrestricted land use. Land use controls would include continuing the existing and installing new access restrictions; maintaining cover materials including grass and asphalt; maintaining fencing and signs; land use restrictions to prohibit changes in land and groundwater uses or construction in impacted soils; and periodic inspection of the site to determine any changes in land use. Periodic environmental monitoring (i.e., soils, surface water, sediment, and groundwater) would be conducted to assess contaminant migration. Remedial action would require 2 years to complete and would include a 1,000 year O&M period. Five-year reviews would be conducted in accordance with CERCLA 121(c).</p> <p>Alternative 7, 8, or 9 would be implemented with this alternative to remediate groundwater. The impact of this alternative on each of the groundwater alternatives is the same.</p>
<p>Alternative 4 – Excavation of Soils and Off-site Disposal (Soils) ~ Industrial Land Use</p> <p>This alternative would involve the removal and transportation of impacted soils above industrial land use cleanup goals for off-site disposal. Impacted soils would be excavated and transported to an off-site disposal facility licensed or permitted to accept these wastes. Clean backfill would be placed in excavated areas. Land use controls would include continuing the existing access restrictions; land use restrictions to prohibit changes in land uses; and periodic inspection of the site to determine any changes in land use. Periodic environmental monitoring (i.e., soils, surface water, and sediment) would be conducted to assess potential for off-site contaminant migration. Remedial action would require 1.7 years to complete and would include a 1,000 year O&M period. Five-year reviews would be conducted in accordance with CERCLA 121(c).</p> <p>Alternative 7, 8, or 9 would be implemented with this alternative to remediate groundwater. The impact of this alternative on each of the groundwater alternatives is the same.</p>
<p>Alternative 5 – Excavation of Soils and Off-site Disposal (Soils) ~ Unrestricted Land Use</p> <p>This alternative would involve the removal and transportation of impacted soils above unrestricted land use cleanup goals for off-site disposal. Impacted soils would be excavated and transported to an off-site disposal facility licensed or permitted to accept these wastes. Clean backfill would be placed in excavated areas. Remedial action would require 3 years to complete. There is no O & M associated with this alternative because impacted soils are removed from the site.</p> <p>Alternative 7, 8, or 9 would be implemented with this alternative to remediate groundwater. The impact of this alternative on each of the groundwater alternatives is the same.</p>

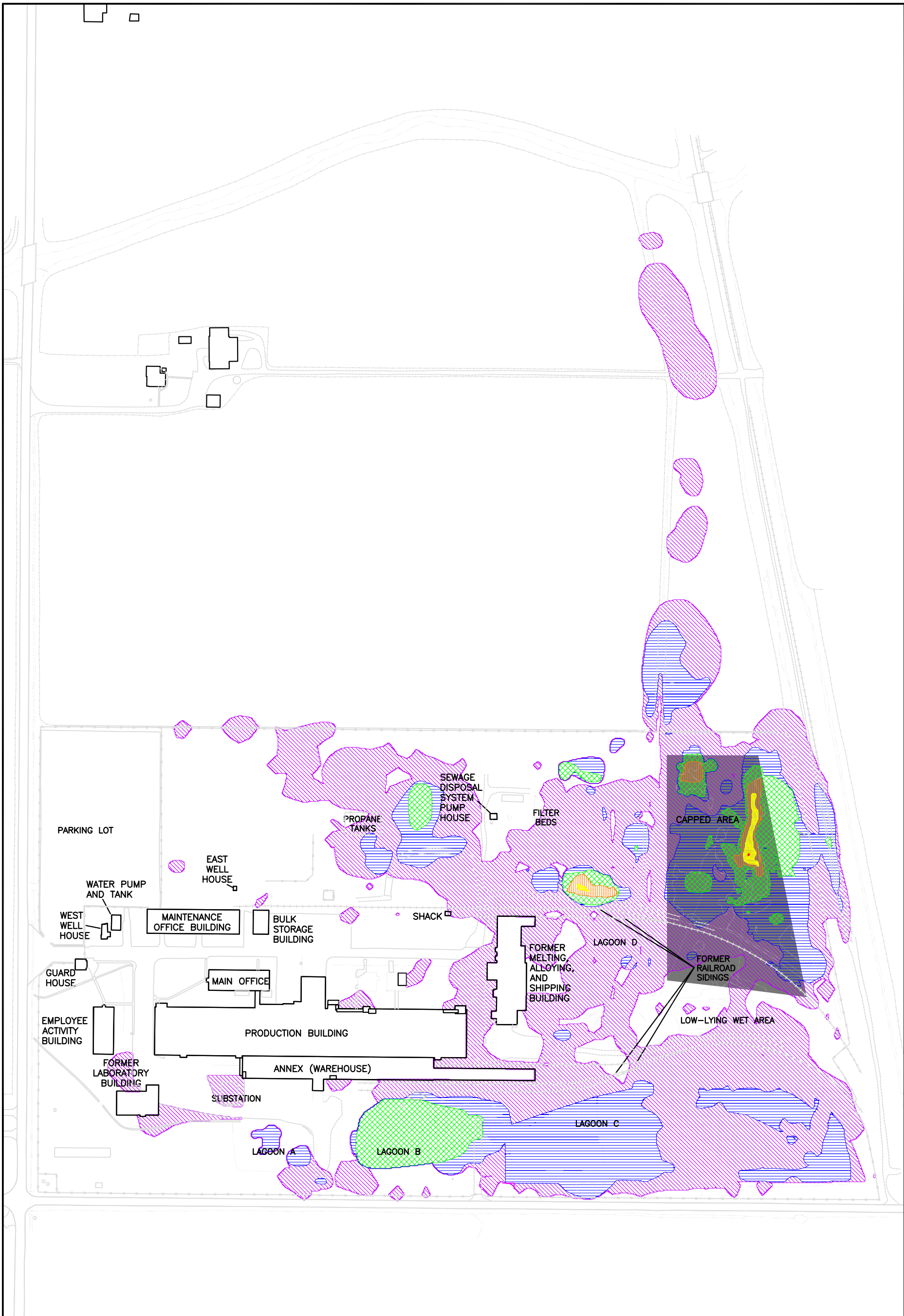
Table 5.1. Summary of Remedial Alternatives

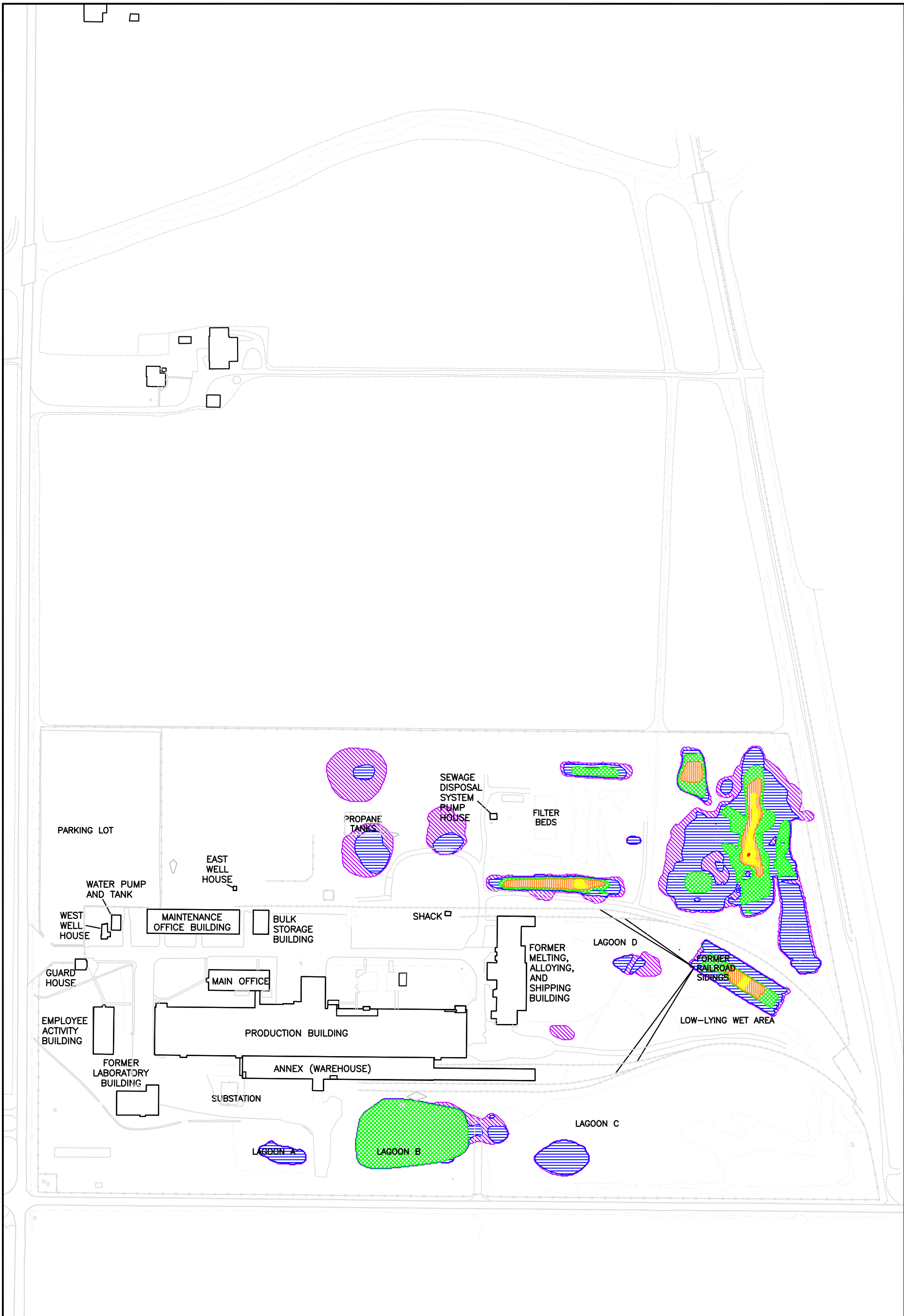
<p>Alternative 6 – Excavation of Soils, Treatment, and Off-site Disposal (Soils) ~ Unrestricted Land Use</p> <p>This alternative is similar to Alternative 5 with respect to the excavation and transportation of soils, cleanup goals, and off-site disposal of impacted soils. However, this alternative incorporates treatment to reduce the volume of contaminated materials requiring disposal. Soils successfully treated to meet cleanup goals would be used as backfill in excavated areas. Impacted soils and treatment residuals above unrestricted land use cleanup goals would be transported to an off-site disposal facility licensed or permitted to accept these wastes. Remedial action would require 3 years to complete. There is no O & M associated with this alternative because impacted soils are removed from the site.</p> <p>Alternative 7, 8, or 9 would be implemented with this alternative to remediate groundwater. The impact of this alternative on each of the groundwater alternatives is the same.</p>
<p>Alternative 7 -- Monitored Natural Attenuation (Groundwater) ~ Unrestricted Land Use</p> <p>This alternative consists of monitoring the reduction in groundwater contaminant concentrations over time and would be implemented in conjunction with Alternative 3, 4, 5, or 6, which effectively remove the sources contributing to groundwater contamination. The impact of Alternatives 3, 4, 5, and 6 on the groundwater would be the same, removal of the source material. Groundwater remedial action would require zero years to complete with a potential 150-year O&M period for groundwater monitoring. Groundwater monitoring would be conducted in accordance with the monitoring program for the first five to 10 years after source removal, after which the efficacy of MNA will be confirmed. Land use controls would include land use restrictions to prohibit changes in groundwater use and periodic inspection of the site to determine any changes in land use. Five-year reviews would be conducted in accordance with CERCLA 121(c).</p>
<p>Alternative 8 – Active Groundwater Treatment, Ex situ Treatment (Groundwater)~ Unrestricted Land Use</p> <p>This alternative consists of actively treating groundwater contaminant concentrations using a pump and treat system involving adsorption of uranium and beryllium onto solid media. It would be implemented in conjunction with Alternative 3, 4, 5, or 6, which effectively remove the sources contributing to groundwater contamination. The impact of Alternatives 3, 4, 5, and 6 on the groundwater would be the same; removal of the source material. Groundwater remedial action would require 80 years for beryllium and 10 years for uranium to complete with an 80-year O&M period for groundwater monitoring. Groundwater monitoring would be performed annually for the first 5 years after source removal to confirm effectiveness. Land use controls would include continuing the existing and installing new access restrictions; maintaining fencing and signs; land use restrictions to prohibit changes in groundwater use; and periodic inspection of the site to determine any changes in land use. Five-year reviews would be conducted in accordance with CERCLA 121(c).</p>
<p>Alternative 9 – Electrokinetics (Groundwater) ~ Unrestricted Land Use</p> <p>Alternative 9 involves drilling a grid pattern of wells through the saturated clay to the fractured bedrock, and emplacement of electrodes encased in permeable membranes filled with electrolyte. The electrodes would be connected to a power source, and the metal contaminants in the groundwater would be driven to the anodes for removal and disposal. This alternative would be implemented in conjunction with Alternative 3, 4, 5, or 6, which effectively remove the sources contributing to groundwater contamination. The impact of Alternatives 3, 4, 5, and 6 on the groundwater would be the same; removal of the source material. Groundwater monitoring would be performed annually for the first 5 years after source removal for up to 15 years during electrokinetic treatment. Groundwater monitoring of constituents in bedrock would continue up to an additional 25 years. Land use controls would include continuing the existing and installing new access restrictions; maintaining fencing and signs; land use restrictions to prohibit changes in groundwater uses; and periodic inspection of the site to determine any changes in land use. Five-year reviews would be conducted in accordance with CERCLA 121(c).</p>

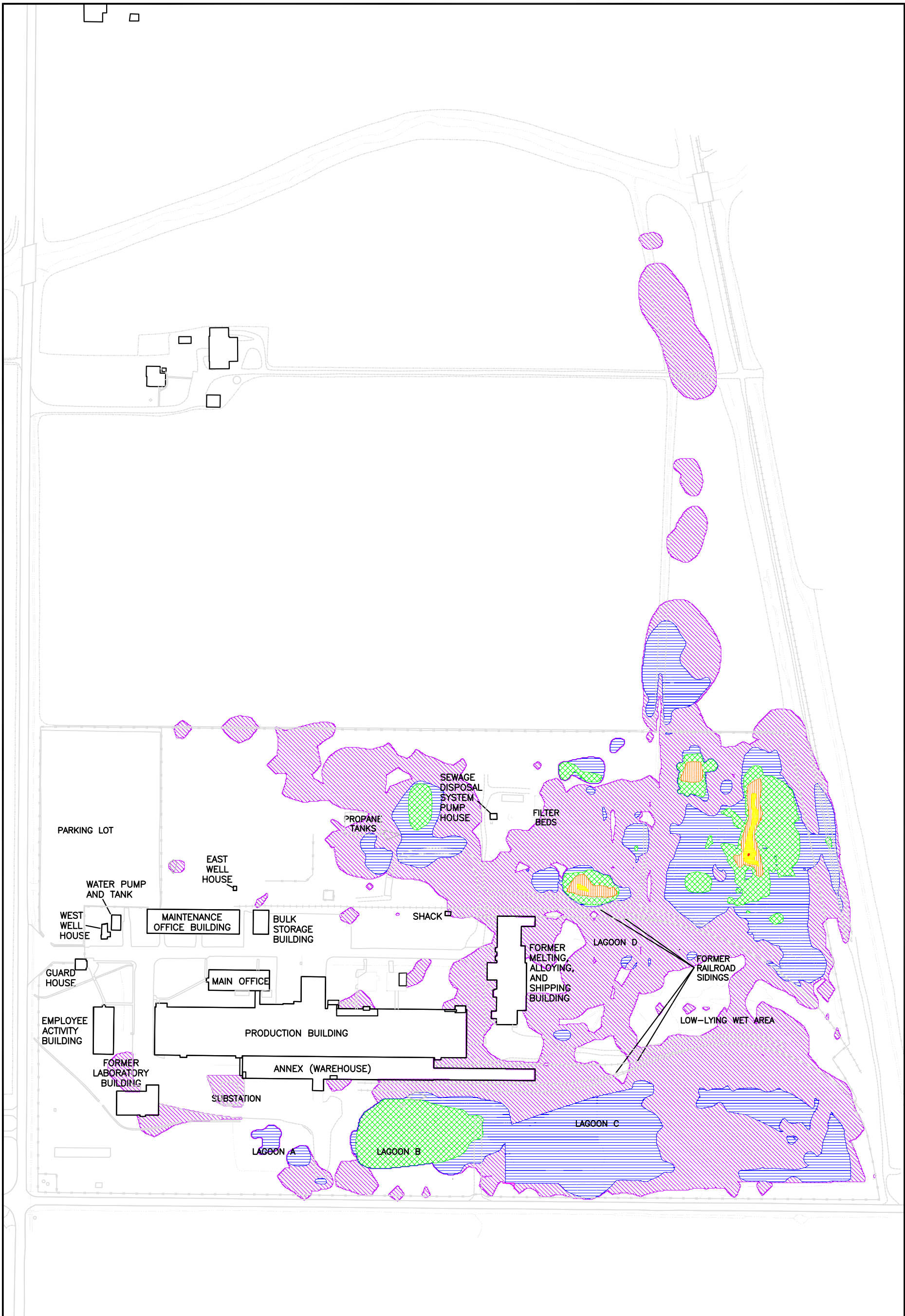
This site map illustrates the layout of the former Alameda County Landfill and Resource Recovery Center. The map includes the following labeled areas and features:

- Buildings and Structures:**
 - PRODUCTION BUILDING
 - ANNEX (WAREHOUSE)
 - MAIN OFFICE
 - MAINTENANCE OFFICE BUILDING
 - BULK STORAGE BUILDING
 - SHACK
 - FORMER MELTING, ALLOYING, AND SHIPPING BUILDING
 - FORMER LABORATORY BUILDING
 - EMPLOYEE ACTIVITY BUILDING
 - GUARD HOUSE
 - WEST WELL HOUSE
 - EAST WELL HOUSE
- Infrastructure and Utilities:**
 - PARKING LOT
 - WATER PUMP AND TANK
 - PROPANE TANKS
 - SEWAGE DISPOSAL SYSTEM PUMP HOUSE
 - FILTER BEDS
 - SUBSTATION
- Water Features and Environmental Areas:**
 - LAGOON A
 - LAGOON B
 - LAGOON C
 - LAGOON D
 - LOW-LYING WET AREA
 - FORMER RAILROAD SIDINGS
 - CAPPED AREA

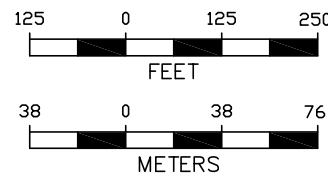
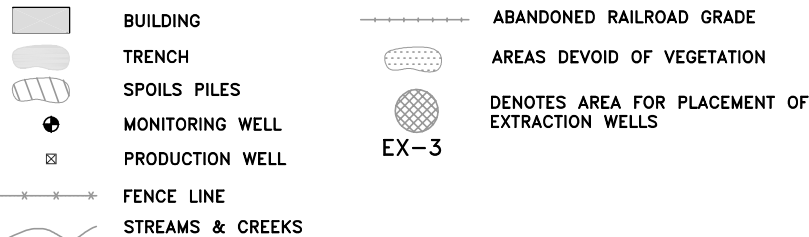
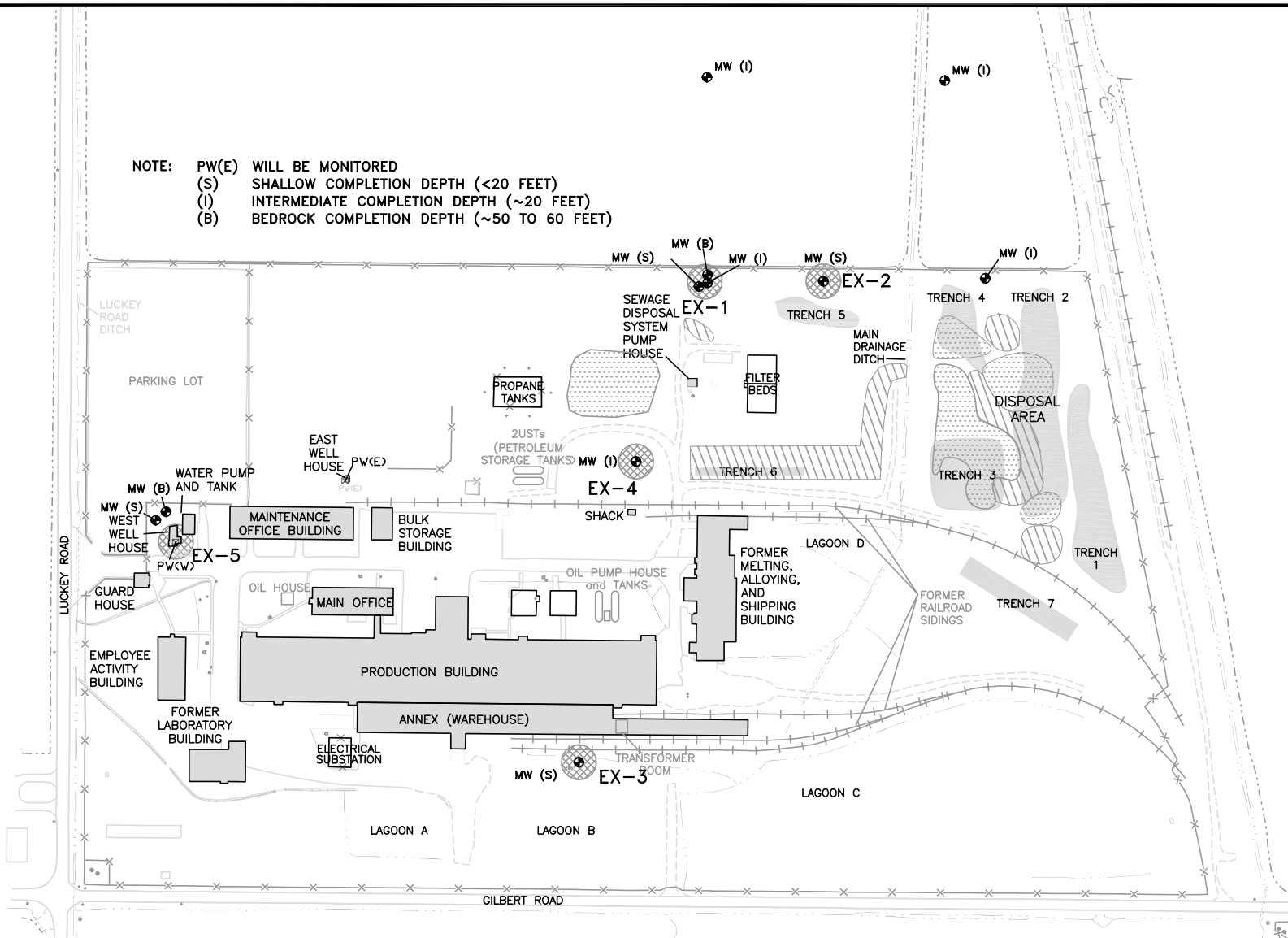
The map uses various colors and patterns to delineate these areas: green for lagoons, blue for wet areas, yellow for the capped area, and different shades of gray and white for buildings and infrastructure. A north arrow is located in the upper right corner of the map.







NOTE: PW(E) WILL BE MONITORED
 (S) SHALLOW COMPLETION DEPTH (<20 FEET)
 (I) INTERMEDIATE COMPLETION DEPTH (~20 FEET)
 (B) BEDROCK COMPLETION DEPTH (~50 TO 60 FEET)



U.S. Army Corps of Engineers
 Buffalo District



LUCKEY SITE
 FS REPORT

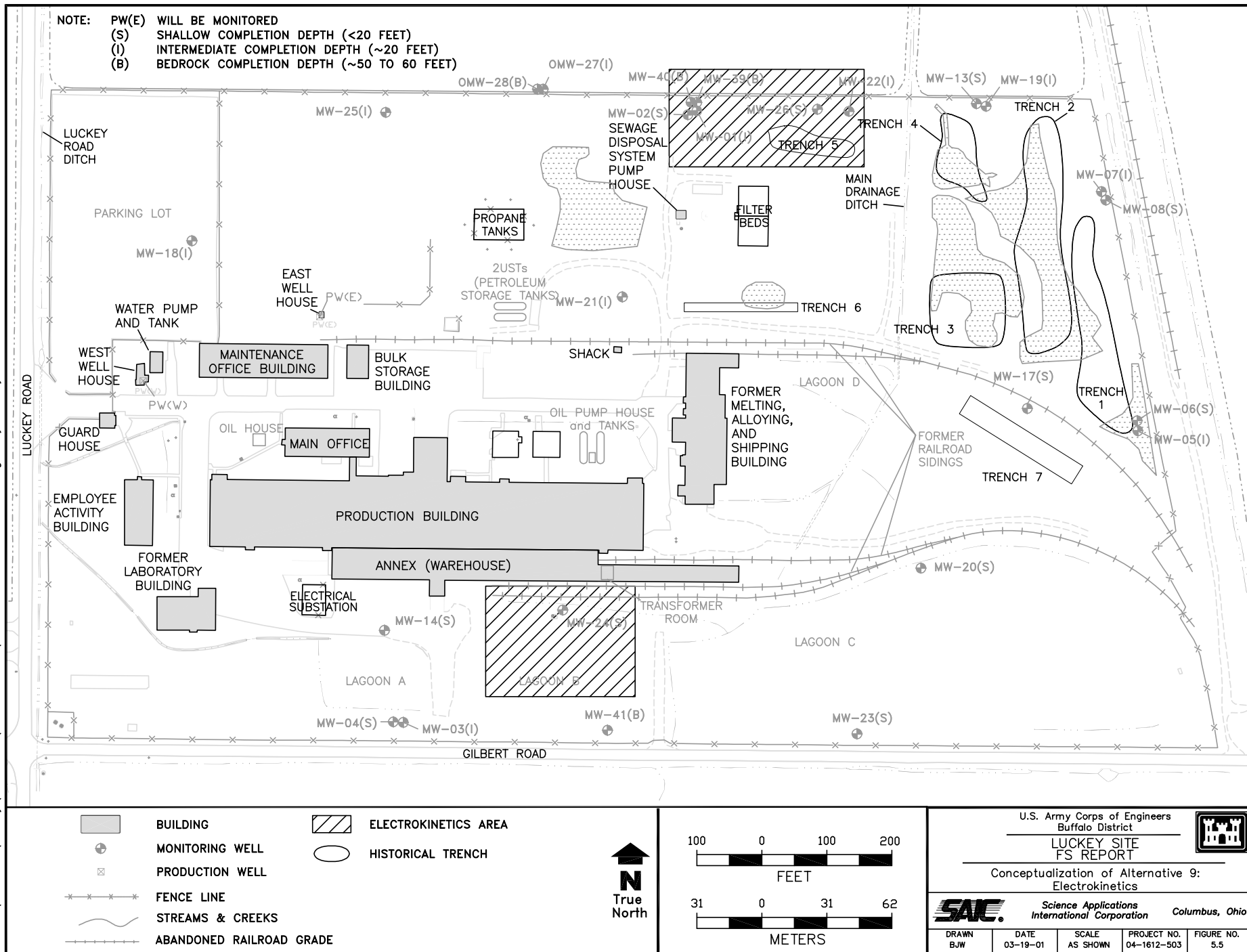
Conceptualization of Alternatives 7 & 8:
 MNA & Active Groundwater Treatment



Science Applications
 International Corporation

Columbus, Ohio

DRAWN BJW	DATE 03-19-01	SCALE AS SHOWN	PROJECT NO. 08-1724-203	FIGURE NO. 5.4
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6.0 ANALYSIS OF REMEDIAL ALTERNATIVES

6.1 INTRODUCTION

This section presents a detailed analysis of the nine remedial alternatives that have been formulated for further evaluation. From this set of alternatives, one or more will ultimately be chosen as the remedy for the soils and groundwater at the Luckey site. Under the CERCLA remedy selection process, the preferred remedial alternative is suggested in the Proposed Plan (PP) and set forth in final form in the Record of Decision (ROD). A detailed evaluation of each alternative is performed in this section to provide the basis and rationale for identifying a preferred remedy and preparing the PP.

To ensure the FS analysis provides information of sufficient quality and quantity to justify the selection of a remedy, it is helpful to understand the requirements of the remedy selection process. This process is driven by the requirements set forth in CERCLA Section 121. In accordance with these requirements (EPA 1988), remedial actions must:

- Be protective of human health and the environment
- Attain ARARs or provide grounds for justifying a waiver
- Be cost effective
- Use permanent solutions and alternative treatment technologies to the maximum extent practicable
- Satisfy the preference for treatment that, as a principle element, reduces volume, toxicity, or mobility.

CERCLA emphasizes long-term effectiveness and related considerations for each remedial alternative. These statutory considerations include:

- Long-term uncertainties associated with land disposal
- The goals, objectives, and requirements of the Solid Waste Disposal Act
- The persistence, toxicity, and mobility of hazardous substances, and their propensity to bio-accumulate
- Short- and long-term potential for adverse health effects from human exposure
- Long-term maintenance costs
- The potential for future remedial action costs if the remedial alternative in question were to fail
- The potential threat to human health and the environment associated with excavation, transportation, and re-disposal, or containment.

These statutory requirements are implemented through the use of nine evaluation criteria presented in the NCP. These nine criteria are grouped into threshold criteria, balancing criteria, and modifying criteria, as described below. Following this description, in Section 6.2, is a detailed analysis of each alternative against the evaluation criteria that includes further definition of each alternative, if necessary, to more accurately describe volumes or areas of contaminated media or technologies. Following this detailed analysis is a brief description of considerations common to all alternatives (Section 6.3) and a comparative analysis (Section 6.4) among the alternatives to assess how each will perform with respect to the criteria.

6.1.1 Threshold Criteria

Two of the NCP evaluation criteria relate directly to statutory findings that must be made in the ROD. These criteria are thus considered to be threshold criteria that must be met by any remedy in order to be selected. The criteria are:

- (1) Overall protection of human health and the environment and
- (2) Compliance with ARARs.

Each alternative must be evaluated to determine how it achieves and maintains protection of human health and the environment. Similarly, each remedial alternative must be assessed to determine how it complies with ARARs, or, if a waiver is required, an explanation of why a waiver is justified. An alternative is considered to be protective of human health and the environment if it complies with media-specific cleanup goals.

6.1.2 Balancing Criteria

The five balancing criteria represent the primary criteria upon which the detailed analysis of alternatives and the comparison of alternatives are based. They are:

- (3) Long-term effectiveness and permanence,
- (4) Reduction of toxicity, mobility, or volume through treatment,
- (5) Short-term effectiveness,
- (6) Implementability, and
- (7) Cost.

Long-term effectiveness and permanence is an evaluation of the magnitude of residual risk (risk remaining after implementation of the alternative) and the adequacy and reliability of controls used to manage the remaining waste (untreated waste and treatment residuals) over the long term. Alternatives that provide the highest degree of long-term effectiveness and permanence leave little or no untreated waste at the site, make long-term maintenance and monitoring unnecessary, and minimize the need for land use controls.

Reduction of toxicity, mobility, or volume through treatment is an evaluation of the ability of the alternative to reduce the toxicity, mobility, or volume of the waste. The irreversibility of the treatment process and the type and quantity of residuals remaining after treatment also are assessed.

Short-term effectiveness addresses the protection of workers and the community during the remedial action, the environmental effects of implementing the action, and the time required to achieve media-specific cleanup goals.

Implementability addresses the technical and administrative feasibility of implementing an alternative and the availability of various services and materials required during implementation. Technical feasibility assesses the ability to construct and operate a technology, the reliability of the technology, the ease in undertaking additional remedial actions, and the ability to monitor the effectiveness of the alternative. Administrative feasibility is addressed in terms of the ability to obtain approval from federal, state, and local agencies.

Cost analyses provide an estimate of the dollar cost of each alternative. The cost estimates in this report are based on estimating reference manuals, existing USACE contracts, historical costs, vendor quotes, and engineering estimates. The primary methodology used is a quantity take-off method in which

costs are calculated based on a unit cost multiplied by quantity or other input parameters. Costs are reported in base year 2002 dollars, or present value (future costs are converted to year 2002 dollars using a 7 percent discount factor). The present value analysis is a method to evaluate expenditures, either capital or O&M, which occur over different time periods. Present value calculations allow for cost comparisons of different remedial alternatives on the basis of a single cost figure. The capital costs have not been discounted due to their relatively short implementation duration. The cost estimates are for guidance in project evaluation and implementation and are believed to be accurate within a range of -30 percent to +50 percent in accordance with EPA guidance (EPA 2000). The detail used to develop these costs should provide more certainty (-10 to +15 percent). Actual costs could be higher than estimated due to unexpected site conditions or potential delays. Details and assumptions used in developing cost estimates for each of the alternatives are provided in Appendix 6B.

6.1.3 Modifying Criteria

The two modifying criteria below will be evaluated as part of the ROD after the public has had an opportunity to comment on the PP. They are:

- (8) State acceptance and
- (9) Community acceptance.

State Acceptance considers comments received from agencies of the State of Ohio. The primary state agencies supporting this investigation are the Ohio EPA and the Ohio DOH. Comments will be accepted from state agencies on the FS and the preferred remedy presented in the PP. This criterion will be addressed in the responsiveness summary of the ROD.

Community Acceptance considers comments made by the community, including stakeholders, on the alternatives being considered. Input has been encouraged during the ongoing investigation process to ensure the remedy ultimately selected for the Luckey site is acceptable to the public. Comments will be accepted from the community on the FS and the preferred remedy presented in the PP. This criterion will be addressed in the responsiveness summary of the ROD. Because the actions above have not yet taken place, the detailed analysis of alternatives presented below cannot account for these criteria at this time. Therefore, the detailed analysis is carried out only for the first seven of the nine criteria.

6.2 DETAILED ANALYSIS OF REMEDIAL ALTERNATIVES

This section presents a detailed analysis of the retained remedial alternatives. Each alternative is described and evaluated against the criteria outlined in Section 6.1. A summary of this evaluation is included in Table 6.2. Site characterization data and a number of analytical tools provide the foundation for evaluation of the alternatives.

Much of the Luckey site information necessary to evaluate the potential alternatives was compiled and presented in the RI Report (USACE 2000a) and is summarized in Section 2 of this report. As such, it presents a summary of pertinent information regarding the environmental setting, site history, and site characterization including nature and extent of contamination, contaminant fate and transport characteristics, and results from the baseline risk assessment. In addition, the extent and volume of contaminants in soils at the site are further discussed in Section 3.4 of this report.

Other analytical tools employed in the evaluation include modeling that permits predictive analysis while considering site characterization data. Groundwater flow conditions at the site were evaluated through the development of a groundwater flow model (USACE 2001a). The flow model reproduces observed groundwater flow conditions at the site and forms the basis for predictive

simulations of contaminant transport in groundwater under each of the alternatives evaluated. Appendix 6A presents a summary of the modeling performed to support the evaluations. Included in Appendix 6A is an evaluation of the leaching potential of constituents through the vadose zone to the groundwater, geochemical modeling to identify the most likely form of the constituents in the groundwater beneath the site, and transport modeling of constituents within the groundwater beneath the site under pumping (East Production Well in operation) and non-pumping (East Production Well shut down) conditions.

6.2.1 Alternative 1: No Action (Soils and Groundwater)

Under this alternative, impacted soils would remain at current locations. Since impacted soils would remain in place, their impact on groundwater would be unabated. Existing land use controls (maintenance of lagoon covers) and access controls (site security fencing) would be left in place but not necessarily maintained. Environmental monitoring would not be performed. In addition, no restrictions on land use would be pursued. However, the site is assumed to operate in compliance with existing regulations that impose limitations on occupational exposures.

6.2.1.1 Overall Protection of Human Health and the Environment

Alternative 1 is not protective of human health. The BRA for the Luckey site indicates potential future human health risks could exceed the CERCLA acceptable range of 10^{-4} to 10^{-6} ILCR for radiological constituents. The potential future human health risks also could exceed an HI of 1 for non-carcinogenic compounds. For current receptor conditions (i.e., industrial worker), risk levels are within the acceptable cancer risk range (10^{-4} to 10^{-6} ILCR) and do not exceed an HI of 1, however, exposures to lead in soils potentially pose unacceptable risk.

The BRA identified risks to ecological receptors on the site due to beryllium and lead in the on- and off-site soils. Under this alternative there would be no mitigation of these risks. There were no ecological effects quotients or HIs greater than 1 for radionuclides.

Alternative 1 provides no additional protection to human health and the environment over baseline conditions. Luckey site soils that pose potentially unacceptable risks under future-use scenarios (e.g., subsistence/residential farmer/industrial worker) would not be remediated. The risks from direct contact, ingestion, external gamma radiation, and inhalation would continue and could increase over time because current access controls, such as fencing and the existing caps on the lagoons, may not be maintained. The potential for human exposure to contaminants and the potential for off-site migration could increase over time as a result of anthropogenic and natural processes and the deterioration of existing structures and paved surfaces.

Risks associated with exposure to contaminated groundwater are minimal under current conditions, as evaluated in the BRA (USACE 2000a). Beryllium, lead, and uranium were detected in groundwater above ARAR-based cleanup goals. The contamination is isolated and regular monitoring of the on-site monitoring wells and East Production Well is occurring. Beryllium, lead, and uranium were detected in the groundwater encountered immediately above bedrock or in the shallow bedrock (with the exception of the West Production Well). Beryllium was consistently detected above the ARAR-based cleanup goal in MW-01(I), MW-02(S), and the West Production Well. Lead was consistently detected above the ARAR-based cleanup goal in MW-21(I). Uranium was consistently detected above the ARAR-based cleanup goal in MW-24(S).

Groundwater at Luckey is expected to remain above ARAR-based cleanup goals into the future under this alternative. Groundwater will periodically come into contact with contaminated materials beneath the trenches and lagoons resulting in periodic impacts to groundwater. In the future, groundwater

containing beryllium above background may migrate off site. Beryllium concentrations in off-site groundwater are expected to exceed ARAR-based cleanup goals for 1,000 years immediately adjacent to the northern fence line (near MW-01(I), MW-02(S), and MW-26(S)). The predicted concentrations under pumping or non-pumping conditions are expected to be less than the maximum concentrations currently detected on site and are not expected to exceed ARAR-based cleanup goals at the location of current receptors (i.e. East Production Well or resident farmer north of the site). Periodic releases of beryllium to groundwater from beneath the trenches are expected to attenuate within a distance of 300 ft north of the site. Periodic releases of lead and uranium to groundwater are not expected to migrate off site above ARAR-based cleanup goals.

6.2.1.2 Compliance with ARARs

Proposed ARARs for the Luckey site are developed in Section 3 of this FS Report. For convenience, these ARARs, which apply to all of the remedial alternatives, are summarized below:

- An unconditional release TEDE standard of 25 mrem/yr assuming the TEDE is demonstrated to be ALARA for radionuclides in soil (reference 10 CFR Part 20 Subpart E and OAC 3701:1-38-22).
- A conditional release TEDE standard of 25 plus ALARA (with durable land use controls) or 100 mrem/yr plus ALARA (if controls are lost) for radionuclides in soil (reference 10 CFR Part 20 Subpart E).
- An MCL of 4 µg/L for beryllium in groundwater that is an actual or potential source of drinking water (reference 40 CFR Section 141.62(b) and OAC 3745-81-11[B]).
- An action level of 15 µg/L for lead in groundwater that is an actual or potential source of drinking water (reference 40 CFR Section 141.80(c)(1) and OAC 3745-81-80(C)(1)).
- An MCL of 30 µg/L for uranium in groundwater that is an actual or potential source of drinking water (reference 40 CFR Section 141.66[e]).

Alternative 1 does not achieve the media-specific cleanup goals established by these ARARs. Concentrations of radionuclides in the soil would continue to exceed the ARAR-based cleanup goals. Groundwater contaminants (beryllium, lead, and uranium) would also continue to exceed ARAR-based cleanup goals, and could potentially migrate off site.

6.2.1.3 Long-Term Effectiveness and Permanence

Alternative 1 includes no long-term management measures to prevent exposures to or the spread of contamination. Potential future risks occur at levels that exceed the CERCLA acceptable cancer risk range. Although existing site security could provide limited control of exposures to site contaminants, this alternative does not assure controls will remain in place and does not provide any additional new controls in the future. Under future land-use scenarios, there are potential unacceptable risks to human health and the environment, since the impacted soils would remain in place with no controls.

Contamination of groundwater would continue since the source of contamination, site soils, would remain in place. Groundwater modeling results, in conjunction with site characterization data, indicate leaching of constituents through the soils is currently not the primary mechanism for the observed concentrations in groundwater. Rather, periodic saturation of the materials in the disposal trenches and subsequent release to groundwater are more likely. These processes would continue to impact groundwater at concentrations exceeding ARAR-based cleanup goals in the shallow groundwater (upper 5-10 ft of saturated thickness). Periodic direct contact between groundwater and contaminated materials beneath the trenches and lagoons is expected to occur for over 1,000 years into the future as

well. Leaching of AEC-related constituents through clay-rich till is not expected to cause groundwater impacts above ARAR-based cleanup goals.

Under this alternative, natural attenuation is the only means for reducing contaminant concentrations in groundwater. Beryllium, lead, and uranium do not biodegrade. The primary mechanisms for attenuation of these contaminants consist of sorption of the aquifer matrix (i.e., soil), chemical reactions, and mixing through mechanical dispersion and diffusion.

Contaminants in groundwater are predicted to migrate towards the East Production Well and remain within its hydraulic influence as long as it operates at its current measured pumping rate (approximately 70 gal/min). Modeling of observed beryllium, lead, and uranium concentrations in groundwater at the site predicts future concentrations at the East Production Well will never exceed ARAR-based cleanup goals.

Beryllium, lead, and uranium tend to sorb to soils, with the amount of sorption increasing as silt and clay content increase. As a result, these constituents tend to move very slowly in overburden areas where they encounter predominantly clay-rich tills. Sorption of contaminants within the bedrock aquifer is expected to be significantly less, permitting the contaminants to migrate more rapidly. However, as the contaminants move through the bedrock, concentrations are reduced through mechanical dispersion and diffusion. As a result of these processes, impacts to groundwater above ARAR-based cleanup goals are generally expected to remain in the areas, or within about 300 feet of the areas, where they are currently observed.

Under the future land use scenario (e.g., subsistence farmer), if no action were taken, receptors could access contaminants (beryllium, lead, and uranium) in groundwater above ARAR-based cleanup goals in wells installed for domestic supply. However, concentrations do not necessarily pose unacceptable risk. Modeling results predict that although concentrations exceed ARAR-based cleanup goals in the shallow bedrock and overburden, ARAR-based cleanup goals are not exceeded in deeper bedrock where domestic supply wells are generally installed.

6.2.1.4 Reduction of Toxicity, Mobility, or Volume through Treatment

No reduction in contaminant toxicity, mobility, or volume is achieved, because no treatment process is proposed under this alternative.

6.2.1.5 Short-Term Effectiveness

There are no significant short-term human health risks associated with Alternative 1 beyond baseline conditions. There would be no additional short-term health risks to the community, because no remedial actions would be implemented. There would be no transportation risks nor would workers be exposed to any additional health risks. Alternative 1 would not directly cause adverse impacts on soils, air quality, water resources, or biotic resources.

No action allows impacted soils to remain. Current (industrial) and future (industrial or agricultural/subsistence farmer/residential) land uses allow for minimal habitat for ecological receptors and thus minimal exposure (i.e., minimal risk to ecological receptors). The time until protection is achieved is indefinite because no action would be taken.

6.2.1.6 Implementability

No actions are proposed under this alternative.

6.2.1.7 Cost

The present value cost to complete Alternative 1 is zero. As discussed earlier, the no action alternative does not meet NCP threshold evaluation criteria (overall protection of human health and the environment/compliance with ARARs). Therefore, the no action alternative is not likely to be selected as the preferred remedial alternative for the site. As the no action alternative is not likely to be selected, costs associated with conducting five-year reviews will not be determined for this alternative. In addition, there would be no capital costs.

6.2.2 Alternative 2: Limited Action (Soils and Groundwater)

Alternative 2 maintains the current status of the property and includes limited site improvements (i.e. improving cover materials, establishing turf in bare spots) and monitoring to identify potential exposures and detect migration and/or changes in the nature or extent of site contamination. Impacted soils beyond property boundaries would not be addressed under this alternative. Groundwater contamination would naturally attenuate. Land use controls under this alternative include continuing existing access restrictions; maintaining cover materials, including grass; periodic inspection of the property to determine any changes in land use; and controls to prohibit changes in land use, construction in impacted soils, or use of contaminated groundwater. These controls would include measures that will notify future property owners and that will restrict land use changes over the long-term, such as governmental controls, proprietary controls, and informational devices. This alternative also includes development of a long-term management plan that establishes avenues for property owners to contact government agencies and a notification procedure in case of proposed changes in land use, monitoring, or maintenance requirements.

6.2.2.1 Overall Protection of Human Health and the Environment

Overall protection of human health and the environment would be achieved, while land use controls remain in place. Addressing bare spots, maintaining existing covers, and preventing access to impacted soils and groundwater would provide sufficient protection. It is reasonable to expect that with appropriate documentation and procedures, land use controls and limited site improvements can be successfully implemented and would be effective in overall protection of human health and the environment. Despite this assumption, Alternative 2 may not be permanent because land use controls can fail. If this were to happen, human health risks could exceed the CERCLA acceptable cancer risk range and the non-carcinogenic HI of 1. In addition, exposures to lead could exceed acceptable levels based on EPA models. The potential future risk would then be the same as for Alternative 1 for soil and groundwater.

Current (industrial) and future (industrial or agricultural/subsistence farmer/residential) land uses will allow for minimal habitat for ecological receptors and thus minimal exposure (i.e. minimal risk to ecological receptors). Addressing risks to human health also will reduce risks to ecological receptors. In addition, measures will be taken to prevent releases to the environment and direct impacts such as habitat disturbance during remedial alternative implementation.

6.2.2.2 Compliance with ARARs

ARAR-based cleanup goals are detailed under Alternative 1. Alternative 2 would achieve the established 25 mrem/yr TEDE standard for radionuclides, assuming land use controls are maintained (i.e. restricted or industrial land use), but would not achieve the 100 mrem/yr TEDE standard, assuming controls are lost (i.e. unrestricted land use), as illustrated in Appendix 3A. In addition, Alternative 2 would not achieve the ARAR-based cleanup goals for uranium, beryllium, or lead in groundwater for more than 1,000 years.

6.2.2.3 Long-Term Effectiveness and Permanence

Alternative 2 may be protective in the long term. It relies on land use controls and maintenance of limited site improvements to eliminate or reduce exposures to contaminants and attenuation to reduce groundwater contamination. The effectiveness of this approach is related to the adequacy and reliability of the land use controls. Although the potential exists for land use controls to fail, it is reasonable to expect that with appropriate documentation and procedures, land use controls can be successfully implemented and would be effective in protecting human health and the environment.

Under this alternative contaminants will remain on site above the media-specific cleanup goals. As long as contaminants remain on site above media-specific cleanup goals, site reviews would be conducted at least once every five years pursuant to requirements of CERCLA. The purpose of these reviews is to evaluate data obtained from ongoing monitoring and provide information on the presence and behavior of contaminants, as well as to ensure that the land use controls and engineering controls are retaining their effectiveness.

Groundwater modeling results utilized to support the no action alternative also support Alternative 2. The contaminant source is not effectively removed under Alternative 2 and thus contaminants in impacted soils would continue to impact groundwater. As noted under the no action alternative, ARAR-based cleanup goals in groundwater would be exceeded on site for an extended period of time in areas where contaminants occur in saturated silty clay sediments, regardless of the operation of the East Production Well. When pumping, the East Production Well exhibits a cone of influence, effectively keeping contaminants on site. According to the modeling results, ARAR-based cleanup goals are not exceeded in the East Production Well during the simulated period (1,000 years). With the pumping well shut down, contaminants migrate northward and are predicted to move off site. Only beryllium is predicted to move off site above the ARAR-based cleanup goal for an approximate period of 1,000 years immediately adjacent to the northern fence line. Lead and uranium do not migrate off site above their respective ARAR-based cleanup goals.

With land use controls in place, access to groundwater would be restricted under future land use scenarios. Land use controls that would be considered to limit exposures to groundwater include access controls, governmental controls, such as zoning and permitting, proprietary measures, such as easements, and educational or notice measures.

6.2.2.4 Reduction of Toxicity, Mobility, or Volume through Treatment

No reduction in contaminant toxicity, mobility, or volume is achieved, because no treatment process is proposed under this alternative.

6.2.2.5 Short-Term Effectiveness

There would be no additional short-term risks to the community under this alternative. Land use at the Luckey site would be restricted and the economic benefit to the local community would likely be reduced.

Active remedial measures would require zero years to complete and would include a 1,000 year O&M period (Table 6.1). Following the implementation of land use controls, monitoring and five-year reviews would be conducted for 1,000 years.

6.2.2.6 Implementability

Land use controls and site improvements are implementable. No technical difficulties are anticipated in establishing or maintaining monitoring programs, access controls, or cover material. However, this alternative could be difficult to implement from an administrative perspective. Many durable land use controls only can be placed on the property by the property owner. Other durable land use controls require the involvement of local government to implement, monitor, and maintain the controls. Local government involvement occurs on a voluntary basis. However, in some cases the federal government can acquire a real estate interest in land.

6.2.2.7 Cost

The present value cost to complete Alternative 2 is approximately \$1.1 million (in fiscal year [FY] 2002 dollars with a seven percent discount factor). This includes the capital cost of installing wells to monitor groundwater. Operation and maintenance costs (for monitoring and land use controls) are estimated for a 1,000-year period. The imposition of land use controls and the implementation of a land use control plan are included in this cost. In addition, five-year reviews are required throughout the costing period. See Appendix 6B for a detailed description of Alternative 2 costs.

6.2.3 Alternative 3: Consolidation and Capping (Soils)

Alternative 3 includes excavation and on-site consolidation of impacted soils in conjunction with containment and land use controls. Impacted soils above unrestricted land use cleanup goals would be excavated, consolidated at an on-site location, and capped to reduce infiltration and limit exposures. Land use controls would be established for areas of consolidated material. These controls would include physical security, such as fencing and signs, and may include measures that will restrict land use changes over the long-term, such as governmental controls, proprietary controls, and informational devices. This alternative also includes development of a long-term management plan that establishes avenues for property owners to contact government agencies and a notification procedure in case of proposed changes in land use, monitoring, or maintenance requirements. This alternative deals solely with soils, although it does include the rubble in the north central portion of the site. It would be implemented in conjunction with one of the groundwater alternatives (Alternatives 7, 8, or 9) to complete remediation. The following evaluation is summarized in Table 6.2.

6.2.3.1 Overall Protection of Human Health and the Environment

Alternative 3 includes consolidation and capping of impacted soils to meet the media-specific cleanup goals (Table 3.3). Consolidation and capping of these soils would limit risks to within the CERCLA acceptable cancer risk range and would limit toxicity to less than the non-carcinogenic HI of 1. Exposures to lead would be reduced to acceptable levels based on EPA models. In addition, exposure would be below dose-based limits as long as land use controls are maintained. The impacted soils would

be covered with an approximately 13-ft thick multi-media cap, minimizing exposures to site workers and the public. Both the risk- and ARAR-based cleanup goals would be satisfied. Land use controls would be used to limit exposures to contaminants in these areas. However, if land use controls fail, then both the risk- and the ARAR-based cleanup goals could be exceeded.

Consolidation and construction of an impermeable cap would significantly reduce infiltration and migration of contaminants to groundwater. Lead and uranium are strongly sorbed to clays in the soil and would only be released slowly to groundwater. Capping would reduce or eliminate the impact of contaminated soils to groundwater but would not reduce existing contamination. Although impacts to groundwater from impacted soils would be reduced, concentrations in groundwater will persist in local areas. Discussion of the overall protection of human health and the environment for groundwater is presented in the groundwater alternatives evaluation.

Current (industrial) and future (industrial or subsistence/residential farmer) land uses allow for minimal habitat for ecological receptors and thus minimal exposure (i.e. minimal risk to ecological receptors). The remedial actions taken to protect human health also will reduce risks to ecological receptors that occupy or visit the site.

6.2.3.2 Compliance with ARARs

ARAR-based cleanup goals selected for the Luckey site are detailed under Alternative 1. Under Alternative 3, ARARs for radionuclides in soil would be satisfied. Soils under the cap would exceed media-specific cleanup goals associated with unrestricted release, but will still comply with ARARs for radionuclides. The ARAR is satisfied even under the worst-case scenario, where the capped area is, at some future date, leveled and used for subsistence farming and future occupants are exposed to consolidated soils. These soils are assumed to be similar to the 0 to 10-ft source term as described in Appendix 3A and the ARAR-based limit is 100 mrem/yr (assuming loss of site controls). Land use controls must be relied upon to achieve compliance with the 25 mrem/yr limit for radionuclides; however, the 100 mrem/yr limit is still satisfied assuming land use controls are lost.

6.2.3.3 Long-Term Effectiveness and Permanence

Alternative 3 offers long-term effectiveness and permanence. The consolidation of impacted soils would result in a permanent reduction in the surface area associated with impacted soils and thereby reduce the overall risk. Since contaminated material would remain on site, continued land use controls would be required. Land use controls would ensure that operation and maintenance tasks, such as monitoring, would be conducted for as long as necessary. This alternative is not “permanent” because these land use controls could fail. For purposes of this FS, it is assumed that the current environmental monitoring program would continue for a period of time between 200 and 1,000 years. The actual length of the program would be based on the results of the five-year reviews.

Consolidation of impacted soils should effectively reduce long-term contamination of groundwater if impacts to groundwater are considered when identifying excavation and consolidation activities. Capping would reduce the surface water infiltration rate and, as a result, reduce the migration of contaminants to groundwater. Remediation of groundwater and its long term effectiveness is discussed later in the evaluation of the groundwater alternatives.

6.2.3.4 Reduction of Toxicity, Mobility, or Volume through Treatment

No reduction in impacted soil toxicity or volume is achieved. This alternative uses consolidation and containment, but not treatment, to minimize mobility.

6.2.3.5 Short-Term Effectiveness

Community: Minimal risk to the community and current tenant personnel is expected during consolidation and capping of impacted soils. Air quality could be affected by the release of particulates and radon during soil excavation. A network of ambient air monitors would be installed to measure dust emissions during construction activities. Engineering controls would be implemented to ensure emissions do not exceed levels that could pose a risk to human health. Land use controls also would be used to restrict public access to construction areas. Noise levels would increase due to the use of heavy equipment during normal working hours. Other short-term impacts to the community could include traffic disruptions during construction. In addition, the impact of the remediation on the local economy would be fairly significant. An outside contractor would perform the work; therefore, mostly secondary jobs would be impacted. Few local residents would be hired directly by the remediation contractors. However, the remediation workers would be spending money in the local economy for the duration of the remediation.

The short-term use of the site for remedial activities could adversely affect current tenant operations. Planning will be done before implementation of this and any alternative to reduce risks to the current tenants (personnel and operations). Long-term effects on the current tenants also will be taken into account when analyzing this alternative. Certain land use controls, such as easements, may make transfer of the property from one owner to another more difficult.

Workers: Potential occupational exposures to remedial construction workers would result from direct exposure to gamma radiation from impacted soils and from inhalation and ingestion of airborne particulates. Workers would follow an approved site-specific Health and Safety Plan (HASP) describing appropriate levels of personal protective equipment (PPE), personal monitoring devices, and decontamination procedures to minimize exposure to and the spread of contamination. The potential for worker exposure is mitigated through these measures. Personal monitoring devices and a medical monitoring program would be used to ensure workers do not receive exposures resulting in adverse health effects. For the types of contaminants at the Luckey site and the types of actions being considered, there is minimal potential for worker exposure when these measures are implemented appropriately.

Heavy machinery will be operated on site during the implementation of this alternative. Workers will be at risk for accidents and injuries associated with the use of this equipment. These construction risks will be consistent with similar activities at non-contaminated construction sites. The use of PPE, however, could increase some types of construction risks due to the restrictive nature of PPE. All machinery and equipment would be inspected after use, surveyed for radioactivity, and decontaminated if necessary. No occupational or safety barriers that would prevent the implementation of this remedy are foreseen.

Ecological Resources: Terrestrial biota would be impacted by disruption of existing habitat during implementation of remedial actions under Alternative 3. These impacts would be temporary, and would not have significant impact on entire populations, because the existing habitat would be reestablished and other biota similar to those originally present would be expected to rapidly re-colonize the area after application of the final soil cover. Offsite aquatic habitat in downstream areas of Toussaint Creek could be impacted by increased sediment loading due to surface runoff. Erosion control measures would be implemented to minimize these impacts. Consultation with the USFWS and the Ohio Department of Natural Resources (Ohio DNR) indicates no protected species are known to be present at the site.

Engineering Controls: Potential releases to the environment would be controlled with management and engineering practices. Runoff control is especially important for any area draining to a

wetland. The only natural habitat remaining on the site is the wetland area in the east-central portion of the property. The excavation of soil in the wetland would be expected to result in the loss of the characteristics and functions of the wetland, at least during the implementation phase of the remedial action. The wetland could be restored after remedial action is completed. Federal and state wetlands regulations would be followed. Any designated wetlands will be addressed to meet Clean Water Act requirements for protection or mitigation of wetlands impacts.

Hay bales and silt fences would be used to prevent soil transport in surface water runoff. Wetting surface materials with water or dust control chemicals would mitigate fugitive dust impacts. Regular surface wetting can reduce the dust loads from construction sites and storage piles by as much as 50 percent. Chemical wetting agents also can increase the reduction significantly. In addition, storage piles and inactive areas can be covered to reduce wind erosion. Equipment will be decontaminated before leaving the site. Capped areas would be re-vegetated with grass for aesthetics and to minimize erosion. Re-vegetating with native trees, grasses, and wetland plants to be compatible with future land uses would restore the disturbed sites.

Time to Complete: Remedial action would require two years to complete and would include a 1,000 year O&M period (Table 6.1). Following completion of excavation, capping, and implementation of land use controls for the site property, monitoring and five-year reviews would be conducted. The potential groundwater alternative also may require additional land use restrictions.

6.2.3.6 Implementability

There are no technical impediments to implementing Alternative 3. The technology is readily available and has been used in similar circumstances to contain both radiological and hazardous contaminants and to prevent migration. Services and materials required to implement this alternative are readily available from the commercial industry. Construction and operation of the components of Alternative 3 would be straightforward. Preventative and other safety measures also are readily implemented to minimize excavation and other exposure risks. Borrow sites for backfill and soil cover have not been selected, but are anticipated to be locally available.

This alternative could be difficult to implement administratively. Moving beryllium-only contaminated waste could result in the need for meeting the substantive requirements of a solid waste permit in the State of Ohio. Also, Ohio law may not allow for disposal of FUSRAP residual radioactive waste within the state. This could create potential difficulties when radiologically contaminated waste is moved for consolidation. Meeting the substantive requirements of a hazardous waste disposal permit also could be necessary if lead-contaminated soil is moved from one area to another. Careful and detailed planning along with multi-agency approval and cooperation may be necessary.

In addition, many durable land use controls only can be placed on the property by the owner of the property. Other durable land use controls require the involvement of local government to implement, monitor, and maintain the controls. Local government involvement occurs on a voluntary basis. However, in some cases the federal government can acquire a real estate interest in land. All of these factors add to the administrative difficulty of implementing this alternative.

Careful planning between remedial action planners and current tenants would be required to minimize disruptions and/or impacts to tenant operations during implementation. Access routes for heavy equipment to remediation areas would be selected to minimize disruption. Additional steps would be taken to minimize hazards to tenant personnel. This type of planning will increase the difficulty of implementability, but also will reduce the risks to personnel.

6.2.3.7 Cost

The present value cost to complete Alternative 3 (in FY 2002 dollars) is approximately \$17.6 million. Costs are based on consolidating and capping accessible impacted soils within the Luckey site. Operation and maintenance costs (for monitoring and land use controls) are estimated for a 1,000-year period. In addition, five-year reviews are required throughout the costing period. See Appendix 6B for a detailed description of Alternative 3 costs.

6.2.4 Alternative 4: Excavation of Soils and Off-site Disposal (Soils) ~ Industrial Land Use

Alternative 4 includes excavation and off-site disposal to remove impacted soils exceeding established media-specific cleanup goals for industrial land use. Soils above the established cleanup goals would be excavated and shipped off site to a permitted disposal facility. Contaminated rubble, which may be encountered from some areas of the site, would be crushed or broken up to meet requirements of the receiving facility. Other technologies required include land use controls, monitoring, short-term containment technologies, and truck and rail transportation. Land use controls to prohibit changes in land use or use of contaminated groundwater would include measures to notify future property owners and to restrict land use changes over the long-term, such as governmental controls, proprietary controls, and informational devices. This alternative also includes development of a long-term management plan to establish avenues for property owners to contact government agencies and a notification procedure in case of proposed changes in land use, monitoring, or maintenance requirements. This alternative addresses soils. Groundwater remediation is discussed in Alternatives 7, 8, and 9. One of those alternatives would be implemented in conjunction with this alternative to provide a complete remediation solution.

6.2.4.1 Overall Protection of Human Health and the Environment

In general, the long-term protectiveness of this alternative is high for industrial land use. Alternative 4 includes removal of soil to meet the industrial land use cleanup goals in surface and subsurface soils (Table 3.3). Remedial activities would address non-radiological and radiological contaminants. Removing soil containing contaminants above media-specific cleanup goals would limit risks to within the CERCLA acceptable cancer risk range. Exposures to lead would be reduced to acceptable levels based on EPA models. In addition, exposure would be below dose-based limits for the industrial worker and recontamination of groundwater would be eliminated. This alternative is protective of human health under industrial land use.

Non-radiological and radiological contaminants would remain above unrestricted land use cleanup goals. Exposure would be prevented as long as land use controls are maintained. If land use controls fail, risks may exceed the CERCLA acceptable cancer risk range and the non-carcinogenic HI of 1 for the unrestricted land use receptor.

Current and future (industrial) land uses allow for minimal habitat for ecological receptors and thus minimal exposure. The remedial actions taken to protect human health also will reduce risks to ecological receptors that occupy or visit the site.

6.2.4.2 Compliance with ARARs

ARAR-based cleanup goals are presented in Section 6.2.1.2 under Alternative 1. Alternative 4 would achieve the established 25 mrem/yr TEDE standard for radionuclides, assuming industrial land use is maintained, and would achieve the 100 mrem/yr TEDE standard by design, assuming land use controls are lost.

6.2.4.3 Long-Term Effectiveness and Permanence

Alternative 4 is protective in the long term for industrial land use. However, it relies on land use controls to eliminate or reduce exposures to receptors associated with unrestricted land use. The long-term effectiveness of this approach is directly related to the adequacy and reliability of the established land use controls. Although the potential exists for land use controls to fail, it is reasonable to expect that, with appropriate documentation and procedures, land use controls can be successfully implemented and would be effective in protecting human health and the environment.

Under Alternative 4, contaminants will remain on site above the media-specific cleanup goals for unrestricted land use. However, they will be below the cleanup goals for industrial land use. As long as contaminants remain on site above media-specific cleanup goals, site reviews would be conducted at least once every five years, pursuant to requirements of CERCLA. The purpose of these reviews is to evaluate data obtained from ongoing monitoring, to provide information on the presence and behavior of contaminants, and to ensure engineering controls and land use controls are retaining their effectiveness.

Removal of impacted soils under this alternative would effectively reduce the long-term contamination of groundwater. Remediation of the current groundwater contamination is covered in Alternatives 7, 8, and 9.

6.2.4.4 Reduction of Toxicity, Mobility, or Volume through Treatment

No reduction in contaminant toxicity, mobility, or volume is achieved, because no treatment process is proposed under this alternative.

6.2.4.5 Short-Term Effectiveness

Short-term effectiveness of Alternative 4 is similar to Alternatives 3 and 5. Excavated soils will be transported by truck to a staging area where intermodals or trucks will be loaded and transported (via truck) to a railroad spur. The soil will be shipped to an out-of-state disposal facility via railcar. Risks will be mitigated during transport by inspecting vehicles before and after use, decontaminating when needed, covering the transported waste, observing safety protocols, following pre-designated routes, and limiting the distance the waste is transported in vehicles. Transportation risks (e.g., from continuous leaks and to trespassers specifically) increase with distance and volume. Transportation of radioactively contaminated materials to an off-site disposal facility would strictly comply with all applicable state and federal regulations. Pre-designated routes would be traveled and an emergency response program would be developed to respond to any accidents. Mitigation measures would be used to ensure minimization of short-term impacts such as erosion and dust control during construction.

Remedial action would require 1.7 years to complete and would include a 1,000 year O&M period (Table 6.1). Following completion of excavation and restoration, the site soils would be released for industrial land use. Following implementation of land use controls for the site property, monitoring and five-year reviews also would be conducted. However, the potential groundwater alternative may require additional land use restrictions.

6.2.4.6 Implementability

Technically, this alternative is highly implementable. Excavation of impacted soils, construction of temporary roads, and on-site truck transport of soil are conventional activities in construction projects of this kind. Multiple disposal facilities are available that can accept the waste. Construction and operation of the components of Alternative 4 would be straightforward. Resources are readily available

for removing soil and standard excavation and construction equipment would be used. Special engineering techniques involving precautions on excavation near buildings and structures also would be observed during remediation. Borrow sites for backfill and soil cover have not been selected, but are anticipated to be locally available.

The acceptability of Alternative 4 would be affected by the administrative requirements for transport and disposal and the requirements for restricted land use. The DOT regulates the transport of most radioactive and chemically hazardous materials. Some states also have their own additional requirements. Depending upon the types and activities of radioactivity being transported, the material may be subject to such requirements. Consultation with the local Engineer departments would be undertaken to evaluate the impact of the truck traffic on the narrow farm roads that surround the Luckey site. A preliminary assessment of transportation options is presented in Appendix 4B.

Land use controls are implementable. No technical difficulties are anticipated in establishing or maintaining monitoring programs, access controls, or cover material. However, this alternative could be difficult to implement from an administrative perspective. Some durable land use controls require the involvement of local government to implement, monitor, and maintain the controls. Local government involvement occurs on a voluntary basis. However, in some cases the federal government can acquire a real estate interest in land.

Careful planning would be needed between remedial action planners and current tenants to minimize disruptions and/or impacts to tenant operations during implementation. Access routes for heavy equipment to remediation areas would be selected to minimize disruption. Additional steps would be taken to minimize hazards posed to tenant personnel. This type of planning will increase the difficulty of implementability, but also will reduce the risks to personnel.

6.2.4.7 Cost

The present value cost to complete Alternative 4 (in FY 2002 dollars) is approximately \$29.3 million. Costs are based on excavation and off-site disposal of accessible impacted soils.

Operation and maintenance costs (for monitoring and land use controls) are estimated for a 1,000-year period. The imposition of land use controls and the implementation of a land use control plan are included in this cost. In addition, five-year reviews are required throughout the costing period. See Appendix 6B for a detailed description of Alternative 4 costs.

6.2.5 Alternative 5: Excavation of Soils and Off-site Disposal (Soils) ~ Unrestricted Land Use

Alternative 5 includes excavation and off-site disposal to remove impacted soils exceeding established media-specific cleanup goals for unrestricted land use (subsistence farmer receptor). Soils above the established cleanup goals would be excavated and shipped off site to a permitted disposal facility. Contaminated rubble, which may be encountered from some areas of the site, would be crushed or broken up to meet requirements of the receiving facility. Other technologies required include land use controls, monitoring, short-term containment technologies, and truck and rail transportation. This alternative deals only with soils. Groundwater remediation is discussed in Alternatives 7, 8, and 9. One of those alternatives would be implemented in conjunction with this alternative to provide a complete remediation solution.

6.2.5.1 Overall Protection of Human Health and the Environment

In general, the long-term protectiveness of this alternative is high. Alternative 5 includes removal of soil to meet the media-specific cleanup goals in surface and subsurface soil. Remedial activities would address non-radiological and radiological contaminants. Removing soil containing contaminants above media-specific cleanup goals would limit risks to within the CERCLA acceptable cancer risk range and to less than the non-carcinogenic HI of 1. Exposures to lead would be reduced to acceptable levels based on EPA models. In addition, exposure would be below dose-based limits and recontamination of groundwater would be eliminated. Therefore, this alternative is protective of human health.

Current (industrial) and future (industrial or agricultural/subsistence farmer/residential) land uses allow for minimal habitat for ecological receptors and thus minimal exposure. The remedial actions taken to protect human health also will reduce risks to ecological receptors that occupy or visit the site.

6.2.5.2 Compliance with ARARs

ARAR-based cleanup goals selected for the Luckey site were detailed under Alternative 1. Under Alternative 5, all soil cleanup goals established by ARARs would be satisfied.

6.2.5.3 Long-Term Effectiveness and Permanence

Alternative 5 is protective in the long term. All soils above the media-specific cleanup goals are excavated and transported off site for disposal, thereby mitigating risks to human health and the environment. Removal of impacted soils would effectively reduce the long-term contamination of groundwater. Remediation of the current groundwater contamination is covered in Alternatives 7, 8, and 9.

6.2.5.4 Reduction of Toxicity, Mobility, or Volume through Treatment

No reduction in impacted soils toxicity, mobility, or volume is achieved. This alternative uses excavation and off-site disposal, but not treatment, to remove soil exceeding media-specific cleanup goals.

6.2.5.5 Short-Term Effectiveness

Short-term effectiveness of Alternative 5 is similar to Alternatives 3 and 4. Excavated soils will be transported by truck to a staging area where intermodals or trucks will be loaded and transported (via truck) to a railroad spur or the local disposal facility. Approximately 64 percent of the soil to be remediated can be disposed at local facilities, since it is neither radioactive nor hazardous. The remainder will be shipped to an out-of-state disposal facility via railcar. Risks will be mitigated during transport by inspecting vehicles before and after use, decontaminating when needed, covering the transported waste, observing safety protocols, following pre-designated routes, and limiting the distance the waste is transported in vehicles. Transportation risks (e.g., from continuous leaks and to trespassers specifically) increase with distance and volume. Transportation of radioactively contaminated materials to an off-site disposal facility would strictly comply with all applicable state and federal regulations. Pre-designated routes would be traveled and an emergency response program would be developed to respond to any accidents. Mitigation measures would be used to ensure minimization of short-term impacts, such as erosion and dust control during construction.

Remedial action would require 2.9 years to complete and would include no O&M period (Table 6.1). Following completion of excavation and restoration, the site soils would be released for unrestricted use. However, the potential groundwater alternative may require land use restrictions.

6.2.5.6 Implementability

Technically and administratively, this alternative is highly implementable. Excavation of impacted soils, construction of temporary roads, and on-site truck transport of soil are conventional activities in construction projects of this kind. Multiple disposal facilities are available that can accept the waste. Construction and operation of the components of Alternative 5 would be straightforward. Resources are readily available for removing soil and standard excavation and construction equipment would be used. Special engineering techniques involving precautions on excavation near buildings and structures also would be observed during remediation. Borrow sites for backfill and soil cover have not been selected, but are anticipated to be locally available.

The acceptability of Alternative 5 would be affected by the administrative requirements for transport and disposal. The DOT regulates the transport of most radioactive and chemically hazardous materials. Some states also have their own additional requirements. Depending upon the types and activities of radioactivity being transported, the material may be subject to such requirements. Consultation with the local Engineer departments would be undertaken to evaluate the impact of the truck traffic on the narrow farm roads that surround the Luckey site. A preliminary assessment of transportation options is presented in Appendix 4B.

Careful planning would be needed between remedial action planners and current tenants to minimize disruptions and/or impacts to tenant operations during implementation. Access routes for heavy equipment to remediation areas would be selected to minimize disruption. Additional steps would be taken to minimize hazards posed to tenant personnel. This type of planning will increase the difficulty of implementability, but will also reduce the risks to personnel.

6.2.5.7 Cost

The present value cost to complete Alternative 5 (in FY 2002 dollars) is approximately \$36.5 million. Costs are based on excavation and off-site disposal of accessible impacted soils. Operation and maintenance costs are zero. See Appendix 6B for a detailed description of Alternative 5 costs.

6.2.6 Alternative 6: Excavation of Soils, Treatment, and Off-site Disposal (Soils) ~ Unrestricted Land Use

Alternative 6 includes excavation combined with treatment and off-site disposal to meet media-specific cleanup goals for the subsistence farmer receptor. A number of different contaminants exist in site soils and only the radionuclides are currently expected to be treatable by the selected technology. The remaining soils would be excavated and transported similar to Alternative 5. Contaminated rubble, which may be encountered from some areas of the site, would be crushed or broken up to meet requirements of the receiving facility. Soils containing radionuclides exceeding established ARAR-based cleanup goals would be excavated and treated on site. Treated soils meeting ARARs would be used as backfill. Treated soils and residuals exceeding established ARAR-based cleanup goals would be shipped to a permitted, off-site disposal facility. Excavation, use of road cover, monitoring, short-term containment technologies, and truck and rail transportation are components of this alternative.

6.2.6.1 Overall Protection of Human Health and the Environment

Alternative 6 includes excavation and treatment of soil to meet the media-specific cleanup goals. Remedial activities under Alternative 6 would address both non-radiological and radiological contaminants. Removing soils containing contaminants above established media-specific cleanup goals would limit risks to within the CERCLA acceptable cancer risk range and to less than the non-

carcinogenic HI of 1. Exposures to lead would be reduced to acceptable levels based on EPA models. In addition, exposure would be below dose-based limits. Therefore, this alternative is protective of human health.

Under this alternative groundwater is not addressed. A groundwater alternative (Alternatives 7, 8, and 9) would be implemented in conjunction with this alternative to achieve a complete remediation solution.

Current (industrial) and future (industrial or subsistence/residential farmer) land uses allow for minimal habitat for ecological receptors and thus minimal exposure. The remedial actions taken to protect human health also will reduce risks to ecological receptors that occupy or visit the site.

6.2.6.2 Compliance with ARARs

ARAR-based cleanup goals selected for the Luckey site were detailed under Alternative 1. Under Alternative 6, all ARAR-based cleanup goals would be satisfied.

6.2.6.3 Long-Term Effectiveness and Permanence

The long-term effectiveness and permanence of Alternative 6 is similar to Alternative 5. The excavation and removal of impacted soils would result in a permanent reduction in site risks.

Removing soils to achieve established media-specific cleanup goals would be protective of human health under future use scenarios without dependence on land use controls. This alternative is permanent, because all materials that pose an unacceptable health risk would be removed and placed in a permanent disposal facility. Therefore, no long-term management of soils would be required.

Removal of impacted soils would effectively reduce the long-term contamination and potential for re-contamination of groundwater. One of the groundwater alternatives (Alternatives 7, 8, or 9) would address the remediation of groundwater.

6.2.6.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Soil treatments, such as soil washing, concentrate the contaminants into a smaller volume. The “clean stream” still contains some low concentrations of residual contamination. The total volume of the clean and concentrated stream is larger than the original volume of impacted soils before processing. Toxicity and mobility could be affected by changing the chemical composition of the constituents in the soil. While soil washing mobilizes constituents in order to remove and concentrate them, once separated, the products of both the clean and concentrated stream are more readily handled. Therefore, the changes to toxicity and mobility would be small. Reduction of the contaminated fraction is estimated for costing purposes to be 50 percent of the throughput (Appendix 6B).

6.2.6.5 Short-Term Effectiveness

Short-term effectiveness of Alternative 6 is similar to Alternatives 3, 4, and 5 with the exception of the potential for worker exposure during treatment. The overall risk in implementing this alternative is increased (relative to Alternative 5) because of the handling of wastes during treatment. When performing soil treatment, workers would follow a HASP and wear appropriate PPE to minimize exposures. Mitigation measures would be used to ensure minimization of short-term impacts, such as erosion and dust control during construction.

Remedial action would require three (3) years to complete and would include no O&M period (Table 6.1). Following completion of excavation, treatment, and restoration, the site soils would be released for unrestricted land use. However, the potential groundwater alternative may require land use restrictions.

6.2.6.6 Implementability

Effectiveness and implementation concerns for this alternative include: the ability of the soil treatment process to meet media-specific cleanup goals, logistical and technical problems for pilot demonstrations and scale-up to full-scale operations, local resistance to on-site treatment, demonstrating the achievement of acceptable dose limits when using treatment residuals as backfill.

This alternative is considered to be technically implementable if certain treatment performance criteria can be met. Soil washing technologies are currently available commercially, although site-specific pilot studies will be required prior to remedial action to determine if these technologies could be cost effectively applied to this site. Although it is technically feasible to wash impacted soils, the volume reduction potentially achievable through washing is anticipated to be minimal, based on the geotechnical characteristics of the soils at the Luckey site. Typically, soil washing is most effective if the contaminants of concern are found in one soil fraction (i.e., all the same size) and that fraction is a small percentage of the total soil volume. EPA suggests that an efficiency of 90 percent is ideal (requiring less than 10 percent fines) (EPA 1996b), and the USACE indicates that the technology is applicable mainly to soils with less than 25 percent clay (USACE 2000b). Most of the soils at the Luckey site contain fines (from 40-90 percent silt and clay; from 1-64 percent clay) (USACE 2000a). Results from the RI Report indicate that only 3 of 13 samples analyzed for geotechnical properties met the 25 percent or less clay fraction requirement (USACE 2000a). Therefore, technical implementability is a potential concern for this alternative.

Careful planning would be needed between remedial action planners and current tenants to minimize disruptions and/or impacts to tenant operations. Access routes for heavy equipment to remediation areas would be selected to minimize disruption. Additional steps would be taken to minimize hazards posed to tenant personnel. This type of planning will increase the difficulty of implementability, but also will reduce the risks to personnel.

Other aspects of this alternative, such as excavation and truck transport of soil, are conventional activities in construction projects of this kind. Standard excavation and construction equipment would be used to remove contaminated material. Resources are readily available for removing impacted soils and providing backfill over treated soils. Borrow sites, for backfill and soil cover, have not been selected, but are anticipated to be locally available.

The acceptability of Alternative 6 would be affected by the administrative requirements for transport and disposal. The DOT regulates the transport of most radioactive and chemically hazardous materials. Some states also have their own additional requirements. Depending upon the types and activities of radioactivity being transported, the material may be subject to such requirements. Consultation with the local roads departments would be undertaken to evaluate the impact of the truck traffic on the narrow farm roads that surround the Luckey site. A preliminary transportation assessment is presented in Appendix 4B.

6.2.6.7 Cost

The present value cost to complete Alternative 6 (in FY 2002 dollars) is approximately \$42.8 million. Costs are based on excavation, treatment efficiency, and off-site disposal of accessible impacted

soils. Operation and maintenance costs are zero. See Appendix 6B for a detailed description of Alternative 6 costs.

6.2.7 Alternative 7: Monitored Natural Attenuation (Groundwater) ~ Unrestricted Land Use

Alternative 7 consists of monitored natural attenuation, with source control, as recommended in EPA (1999) guidance. Source control would consist of the implementation of one of the soil alternatives (Alternatives 3, 4, 5, or 6), which would eliminate further addition of mass to groundwater at concentrations above ARAR-based cleanup goals. Natural attenuation processes at the Luckey site are expected to reduce contaminant concentrations through the processes of dispersion, diffusion, and sorption. Sorption of the contaminants onto the soil and rock matrix also reduces the contaminants' mobility and bioavailability. Modeling results indicate contaminated groundwater in the upper 20 feet of bedrock attenuates within 40 years. The beryllium concentrations in the sands and gravels are expected to drop significantly after the source is removed based upon the assumption that periodic wetting of source materials results in the observed groundwater contamination. This assumption is based upon modeling results (which indicate that beryllium leaching through soil to groundwater is not a likely source) and observations of elevated beryllium concentrations at seasonally high groundwater levels. The magnitude of the drop in beryllium levels after source removal is uncertain. Conservative source terms representing the existing beryllium concentration in groundwater were used in fate and transport modeling. Modeling results predict a reduction in beryllium concentrations to cleanup levels in 150 years for the sands and gravels after source removal. Should significant contamination occur within the clay-rich till, natural attenuation time frames could be much longer.

6.2.7.1 Overall Protection of Human Health and the Environment

Alternative 7 includes installation of monitoring wells to monitor attenuation of beryllium, lead, and uranium in groundwater. Monitored natural attenuation would address both non-radiological and radiological contaminants within the groundwater. The further release of contaminants to the groundwater above groundwater ARAR-based cleanup goals also would be eliminated through source control.

Currently there is no unacceptable exposure to these constituents in groundwater. Only beryllium, which occurs in groundwater at the northern fence line, is predicted to move off site for a period of about 40 years in the upper bedrock and up to approximately 150 years in the sand and gravel. This movement is expected to occur over a distance of less than 300 feet. Groundwater within the overburden is predicted to remain above ARAR-based cleanup goals for beryllium, lead, and uranium in the localized areas where they have been detected. Modeling results predict that although concentrations exceed ARAR-based cleanup goals in the shallow bedrock and overburden, ARAR-based cleanup goals are not exceeded in deeper bedrock where domestic supply wells are generally installed. Until groundwater is returned to a condition of compliance, land use controls would restrict the use of groundwater. Therefore, the alternative would be protective of human health.

6.2.7.2 Compliance with ARARs

ARAR-based cleanup goals selected for the Luckey site were detailed under Alternative 1. Under Alternative 7, all ARAR-based cleanup goals in groundwater would be satisfied. With the addition of one of the soil alternatives all ARAR-based cleanup goals would be satisfied.

6.2.7.3 Long-Term Effectiveness and Permanence

The long-term effectiveness and permanence of Alternative 7 is very good. The excavation and removal of impacted soils under one of the soil alternatives would result in a permanent reduction in the risk of recontamination of the groundwater. Natural attenuation would ensure groundwater remediation would be permanent. By removing the source material or preventing additional impacts to groundwater, natural attenuation processes in the groundwater system will eventually reduce concentrations of contaminants below ARAR-based cleanup goals. For purposes of this FS, it is assumed the current environmental monitoring program would continue until natural attenuation had resulted in attainment of groundwater clean-up goals. Five-year reviews would be necessary to confirm groundwater ARAR-based cleanup goals have been attained.

6.2.7.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Under this alternative no actions would be taken to reduce the toxicity, mobility, or volume of contaminants in groundwater. Naturally occurring conditions at the site would act to reduce concentration and mobility. Mobility of the constituents is reduced through the sorption of contaminants onto the clay-rich till and, to a lesser extent, the sands and gravels. Sorption within the bedrock is assumed to be negligible. Concentrations are reduced through the processes of dispersion, diffusion, and sorption as contaminants move through the overburden and the bedrock aquifer.

6.2.7.5 Short-Term Effectiveness

Short-term effectiveness of Alternative 7 is good for groundwater within the bedrock aquifer and could be poor for groundwater within the overburden. This is due to its predicted persistence above ARAR-based cleanup goals, particularly in the event that significant contamination occurs in the clay-rich till. Monitoring, following EPA (1999) guidance, will be used to evaluate short term effectiveness of MNA with respect to overburden and carbonate bedrock groundwater. Land use controls would be placed to restrict the use of groundwater until monitoring has shown the process to be complete. When performing groundwater sampling, workers would follow a HASP and wear appropriate PPE to minimize exposures. Mitigation measures would be used to ensure minimization of short-term impacts, such as erosion and dust control during construction.

Installation of monitoring wells would require less than ¼ year to complete and could include 150 years of O&M (Table 6.1). As indicated earlier, the beryllium concentrations in the sands and gravels are expected to drop significantly after the source is removed based upon the assumption that periodic wetting of source materials results in the observed groundwater contamination. The 150-year O&M period results from the predicted persistence of beryllium in groundwater within the overburden sands and gravels using conservative source terms representing the existing beryllium concentration in groundwater and is therefore included for use in cost estimates. Time frames could be longer in the event that significant contamination exists within the clay-rich till. Time frames also could be shorter. Following completion of monitoring well installation and implementation of land use controls, monitoring and five-year reviews would be conducted.

6.2.7.6 Implementability

This alternative is considered to be technically implementable. Modeling indicates the groundwater contaminants will naturally attenuate within the bedrock aquifer within in a time frame that is considered reasonable for groundwater and could be reasonable for overburden groundwater. Land use controls restricting groundwater use are considered technically implementable.

Drilling and monitoring of groundwater wells is a well known activity and generally does not pose implementation problems. Equipment and personnel are readily available. The wells would be installed to monitor observed occurrences of contaminants in the groundwater and at selected down-gradient locations from probable source areas to demonstrate MNA effectiveness (Figure 5.4). Initially, existing monitoring wells would be used to monitor the effectiveness of MNA. These would be supplemented in instances where monitoring wells no longer exist or require replacement. A long term monitoring plan would be developed for groundwater sampling and reporting requirements.

The acceptability of Alternative 7 would be affected by the administrative requirements for monitoring and the requirement to restrict groundwater use for a lengthy period of time. Imposition of these controls would depend on the cooperation of the current owner and the State. Many durable land use controls can be placed on the property only by the owner of the property. Other durable land use controls require the involvement of local government to implement, monitor, and maintain the controls. Local government involvement occurs on a voluntary basis. However, in some cases the federal government can acquire a real estate interest in land. All of these factors add to the administrative difficulty of implementing this alternative.

6.2.7.7 Cost

The present value cost to complete Alternative 7 (in FY 2002 dollars) is approximately \$0.83 million. Costs are based on installation of monitoring wells. Operation and maintenance costs (for monitoring and land use controls) are estimated for a period up to 150 years. See Appendix 6B for a detailed description of Alternative 7 costs.

6.2.8 Alternative 8: Active Groundwater Treatment – Ex Situ (Groundwater) ~ Unrestricted Land Use

Alternative 8 consists of the installation of a pump and treat system to remove contaminated groundwater from beneath the site and subsequently remove the contaminants via treatment processes. Alternative 8 includes installation of monitoring wells, extraction wells, and a treatment system. Cleanup of contaminated groundwater within the overburden would be completed within 50 to 80 years and within 25 years for contaminated groundwater within the carbonate bedrock based upon predictive modeling results. Time frames for groundwater cleanup could be longer if significant contamination occurs in groundwater within the clay-rich till above the bedrock. Monitoring of groundwater while the treatment system is in operation is included. This alternative would be implemented in conjunction with one of the soil alternatives for a complete remediation solution.

6.2.8.1 Overall Protection of Human Health and the Environment

Remedial activities under Alternative 8 would address both non-radiological and radiological contaminants. Until the groundwater had returned to a condition of compliance, land use controls would restrict the use of groundwater. Therefore, the alternative is protective of human health. The further release of contaminants to the groundwater above ARAR-based cleanup goals in groundwater also would be eliminated through source control.

Currently there is no exposure to these constituents in groundwater. Future off site migration is reduced or eliminated through the operation of the groundwater extraction wells. Until the groundwater is returned to a condition of compliance, land use controls would restrict the use of groundwater. Therefore, the alternative is protective of human health.

6.2.8.2 Compliance with ARARs

ARAR-based cleanup goals selected for the Luckey site were detailed under Alternative 1. Under Alternative 8, all ARAR-based cleanup goals in groundwater would be satisfied. With the addition of one of the soil alternatives, all ARAR-based cleanup goals would be satisfied.

6.2.8.3 Long-Term Effectiveness and Permanence

The long-term effectiveness and permanence of Alternative 8 is similar to Alternative 7. The excavation and removal of impacted soils under one of the soil alternatives would result in a permanent reduction in the risk of recontamination of the groundwater. The extraction and treatment of contaminated groundwater would ensure that when land use controls were lifted, the remediation would be permanent. For the purposes of this FS, it is assumed that an environmental monitoring program would remain part of the alternative until the treatment resulted in groundwater meeting the clean-up goals. Five-year reviews would be necessary to confirm ARAR-based cleanup goals have been attained.

By removing the source material or preventing additional impacts to groundwater and by treating contaminated groundwater, the pump and treat system will reduce concentrations of contaminants to below ARAR-based cleanup goals in a shorter time frame than natural attenuation in both the bedrock aquifer and the overlying sands and gravels. Contaminants in the clay-rich till would be much more difficult to pump and treat.

Dewatering of the relatively thin zones of groundwater contamination in the overburden could limit the long term effectiveness. By dewatering the overburden, contaminants would be left behind within the aquifer matrix. Re-saturation of these materials could result in the recontamination of the groundwater after pump and treat operations had ceased.

6.2.8.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Under this alternative groundwater would be treated to remove contaminants and thus reduce their volume and mobility. Off site migration would be reduced or eliminated through the hydraulic control (groundwater capture zones) produced by the operation of the extraction wells. Extracted groundwater would be piped to an on-site treatment facility where materials such as activated alumina and activated carbon would be used to remove the beryllium, lead, and uranium from the groundwater.

6.2.8.5 Short-Term Effectiveness

Short-term effectiveness of Alternative 8 is good for contaminated groundwater within the carbonate bedrock, but less effective for the overburden materials. Time frames for the remediation of the sands and gravels are roughly one half the time required for the natural attenuation of these materials (50 to 80 years for pump and treat versus 150 years for MNA).

Beryllium remains in the bedrock aquifer for approximately 25 years under pump and treat at one location based upon the current modeling efforts. Land use controls would be placed to restrict the use of groundwater until monitoring has shown the process to be complete. When performing groundwater sampling or servicing the equipment, workers would follow a HASP and wear appropriate PPE to minimize exposures. Mitigation measures would be used to ensure minimization of short-term impacts, such as erosion and dust control during construction and risks associated with treatment system operation (such as accidents/potential releases).

System design and installation would require 1½ year to complete. An 80 year O&M period (Table 6.1) also is included. Following completion of monitoring well installation, and implementation of land use controls for the site property, monitoring and five-year reviews would be conducted.

6.2.8.6 Implementability

Effectiveness of this alternative will be governed by the ability to pump sufficient groundwater to reduce concentrations in the thin zones of contamination without dewatering the soil. The overburden materials at the site contain a thin zone of saturation. Modeling results indicate that pumping from within or below these materials can quickly dewater them. With no water moving through the materials, the constituents remain in place until becoming re-saturated. Modeling results indicate pumping of contaminants from the upper 20 ft of the bedrock aquifer is effective within a reasonable time frame.

This alternative is considered to be technically implementable. Pump and treat systems are a common technology and the anticipated treatment media are available. Drilling and monitoring of groundwater wells is a well known activity and does not pose implementation problems. Equipment and personnel are readily available. Land use controls restricting groundwater use are considered technically implementable.

Careful planning would be needed between remedial action planners and current tenants to minimize disruptions and/or impacts to tenant operations. Access routes for heavy equipment to remediation areas would be selected to minimize disruption. Additional steps would be taken to minimize hazards posed to tenant personnel. This type of planning will increase the difficulty of implementability, but also will reduce the risks to personnel.

The acceptability of Alternative 8 would be affected by the administrative requirements for monitoring and the requirement to restrict groundwater use for a lengthy period of time. The acceptability also could be affected by the necessity of maintaining a treatment system for an extended period of time. Imposition of these controls and continuation of the treatment program would depend on the cooperation of the current owner and the State. Many durable land use controls can be placed on the property only by the owner of the property. Other durable land use controls require the involvement of local government to implement, monitor, and maintain the controls. Local government involvement occurs on a voluntary basis. However, in some cases the federal government can acquire a real estate interest in land. All of these factors add to the administrative difficulty of implementing this alternative.

6.2.8.7 Cost

The present value cost to complete Alternative 8 (in FY 2002 dollars) is approximately \$3.7 million. Costs are based on installation of six extraction wells and 12 monitoring wells. Operation and maintenance costs (for monitoring and land use controls) are estimated for an 80 year period. See Appendix 6B for a detailed description of Alternative 8 costs.

6.2.9 Alternative 9: Electrokinetics (Groundwater) ~ Unrestricted Land Use

Alternative 9 includes the installation of approximately 650 electrode wells in each area of shallow contaminated groundwater in the unconsolidated materials overlying the carbonate bedrock (i.e., in the region encompassing wells MW-02(S) and MW-26(S), and in the area encompassing well MW-24(S)). The electrode wells will consist of 4-inch PVC well casing, screened over the entire depth of the groundwater between the water table and bedrock. Electrodes wrapped in permeable membranes containing electrolyte are lowered into the groundwater. The electrodes are designed to be as long as the screened interval. The electrodes are wired in alternating rows of cathodes and anodes, which create an

electrical field that drives metal contaminants to one set of wells (the anodes). At the anodes, the metal contaminants cross the permeable membrane and remain inside the membrane until the electrolyte is removed, either by pumping or by removal of the electrode once ARAR-based cleanup goals have been reached. To support electrolyte replacement, a network of pipes and acid replenishment tanks would be plumbed to the electrodes. Monitoring of groundwater while the treatment system is in operation is included. This alternative would be implemented in conjunction with one of the soil alternatives for a complete remediation solution.

As discussed in Section 5.8, the presumed number of wells, their spacing, and treatment times for each area of the site are based on engineering judgment consistent with previous applications of the technology. This will provide for cost-effective removal of metal contaminants from the groundwater at the Luckey site. Decreasing the spacing between electrodes would increase capital costs, but reduce operating costs. Increasing the power would reduce treatment time, but increase the cost of the remedial alternative. A pilot-scale field study would be necessary to optimize the numbers of electrodes, their spacing, and treatment time. For purposes of this FS, it is assumed that the well spacing between electrodes will be 3 meters and that the total electrokinetic treatment time will be 15 years for the unconsolidated materials overlying the carbonate bedrock. To minimize the total cost of remediation, it is further assumed that the beryllium-contaminated groundwater will be treated first, and the electrodes will be reused to treat the uranium-contaminated groundwater. Because groundwater in the carbonate bedrock may not be treated with electrokinetics, up to 25 years of monitoring may be required after completion of the electrokinetic remedy (40 years for natural attenuation in carbonate bedrock less the 15 years over which electrokinetics is applied).

6.2.9.1 Overall Protection of Human Health and the Environment

Remedial activities under Alternative 9 would address both non-radiological and radiological contaminants by driving them to the anodes in the groundwater where they would be collected and subsequently removed. This alternative is analogous to established plating and chlor-alkalai industry technologies. Under the influence of the electric field generated by the electrodes, metal contaminants will migrate to the anodes and will concentrate in the electrolyte surrounding the anodes.

Because this alternative results in the removal of metal contaminants from the groundwater, ARAR-based cleanup goals are attained and this alternative is protective of human health. This alternative also minimizes short-term risks to human health because it is an in situ process; thereby not requiring excavation activities. In addition, until the groundwater is returned to a condition of compliance, land use controls would restrict the use of groundwater.

6.2.9.2 Compliance with ARARs

ARAR-based cleanup goals selected for the Luckey site were detailed under Alternative 1. Under Alternative 9, all ARAR-based groundwater cleanup goals would be satisfied because the contaminants would be removed. Used in combination with one of the soil alternatives, all ARAR-based cleanup goals would be satisfied for the site.

6.2.9.3 Long-Term Effectiveness and Permanence

The long-term effectiveness and permanence of Alternative 9 is similar to Alternative 8. The excavation and removal of impacted soils under one of the soil alternatives would result in a permanent reduction in the risk of recontamination of the groundwater. Furthermore, the removal and treatment of contaminants in the groundwater would ensure that, when land use controls were lifted, the remediation would be permanent. For purposes of this FS, it is assumed that an environmental monitoring program

would remain as part of this alternative until the treatment had resulted in groundwater meeting the clean-up goals. Five-year reviews would be necessary to confirm that ARAR-based cleanup goals had been attained.

By removing the source material or preventing additional impacts to groundwater, recontamination of the groundwater would be precluded. The electrokinetic system will remove contaminants from the groundwater, reducing concentrations of contaminants to below the ARAR-based cleanup goals in a shorter time frame than either natural attenuation or pump and treat methods. Additionally, electrokinetics is ideally suited for mobilizing and collecting metal contaminants in tight groundwater formations of low flow or hydraulic conductivity similar to the Luckey site.

6.2.9.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Under this alternative, the toxicity, mobility, and volume of contamination would all be reduced through treatment. This alternative consists of contaminant removal and treatment. Toxicity would be reduced as concentrations of contaminants decrease below ARAR-based cleanup goals. Similarly, contaminant mobility and volume would be reduced through removal from the groundwater.

6.2.9.5 Short-Term Effectiveness

Short-term effectiveness of Alternative 9 is good. Contaminants would migrate to and be collected at the anodes the entire time the treatment system was in operation. Correspondingly, groundwater concentrations would steadily decline. The envisioned treatment time was predicated on minimizing remedial costs. Decreasing treatment times could increase the short-term effectiveness; however, that would increase operating and remediation costs.

Land use controls would be placed to restrict the use of groundwater until monitoring had shown the process to be complete. When performing groundwater sampling or servicing the equipment, workers would follow a HASP and wear appropriate PPE to minimize exposures. Mitigation measures would be used to ensure minimization of short-term impacts such as erosion and dust control during construction and risks associated with system operation (such as accidents/potential releases).

Remedial action would require one (1) year to complete and would include a 40-year O&M period (Table 6.1). Following completion of monitoring well installation and implementation of land use controls for the site property, monitoring and five-year reviews would be conducted.

6.2.9.6 Implementability

Effectiveness and implementation concerns for this alternative include the ability to maintain the current flow through the electrodes at the proper levels and the ability to replenish electrolyte as it becomes saturated. However, at concentrations of contaminants found in groundwater at the Luckey site, electrolyte saturation is not anticipated. In addition, operating parameters are monitored and controlled remotely through a computer processor.

This alternative is considered to be technically implementable. Electrokinetic systems are a relatively new technology, but are based on well-established electrochemical industry processes. Electrokinetic systems are ideally suited for and have worked well in tight formations like those at the Luckey site. Land use controls restricting groundwater use are considered technically implementable. Drilling and monitoring of groundwater wells is a well-established activity and does not pose implementation problems. Equipment and trained personnel are readily available.

Careful planning would be needed between remedial action planners and current tenants to minimize disruptions and/or impacts to tenant operations. Access for heavy equipment to remediation areas would be selected to minimize disruption. Additional steps would be taken to minimize hazards posed to tenant personnel. This type of planning will increase the difficulty of implementability, but also will reduce the risks to personnel.

The acceptability of Alternative 9 would be affected by the administrative requirements for monitoring and the requirement to restrict groundwater use for a lengthy period of time. The acceptability also could be affected by the necessity of maintaining a treatment system, which involves the use of considerable electrical energy. Imposition of these controls and continuation of the treatment program would entail cooperation of both the current owner and the State.

6.2.9.7 Cost

The present value cost to complete Alternative 9 (in FY 2002 dollars) is approximately \$9.4 million. Costs are based on installation of monitoring wells and electrodes. Operation and maintenance costs (for monitoring and land use controls) are estimated for a 40-year period. See Appendix 6B for a detailed description of Alternative 9 costs.

6.3 CONSIDERATIONS COMMON TO ALL ALTERNATIVES

6.3.1 Monitoring and Mitigative Measures

A mitigation action plan would be developed during remedial design to specify measures that would be taken during implementation of the remedial action to minimize risk to human health and the environment (e.g., environmental controls and contingency response actions). The primary monitoring and mitigative measures that would be used at the Luckey site are described below. These measures would be effective in minimizing the potential adverse effects associated with implementation of the alternatives.

Construction Activities: Construction practices to control potential releases to the environment would include management and engineering practices. Hay bales and silt fences would be used to prevent soil transport in surface water runoff. Wetting surface materials with water or dust control chemicals would mitigate fugitive dust impacts. Regular surface wetting can reduce the dust loads from construction sites and storage piles by as much as 50 percent. Chemical wetting agents also can increase the reduction significantly. In addition, storage piles and inactive areas can be covered to reduce wind erosion. Equipment will be decontaminated before leaving the site. Capped areas would be re-vegetated with grass for aesthetics and to minimize erosion. Re-vegetating with native trees, grasses, and wetland plants, to be compatible with future land uses, would restore the disturbed sites. Groundwater, surface water, air, and sediment monitoring would be conducted. Habitat would be restored and mufflers and barriers would be used for noise abatement.

Transportation: Wastes would be containerized and fitted with a cover and/or liner during long distance transport across public roads. The conveyance equipment could be fitted with a cover and/or lined with a barrier. Vehicles would be decontaminated and inspected before leaving contaminated areas.

Worker Protection: Activities would be conducted in accordance with approved health and safety plans. PPE, personal monitoring devices, and decontamination procedures would be used to minimize exposure to and the spread of contamination. The potential for worker exposure is mitigated through these measures. Personal monitoring devices and a medical monitoring program would be used to ensure workers do not receive exposures that would result in adverse health effects.

Protection of the General Public: A network of ambient air monitors would be installed to measure dust emissions during construction activities. Mitigation measures, such as wetting soil, will be implemented if emissions exceed levels that could pose a risk to human health. Access controls also would be used to restrict public access to construction areas

Environmental Restoration: Any portions of the on-site wetlands impacted by remedial actions will be restored to their pre-construction condition. No actions will occur in the floodplain of Toussaint Creek as part of the alternatives outlined in this FS.

6.3.2 Impact of Potential Loss of Land Use Controls

For Alternative 1, land use controls would not be maintained, so there would be no impact if land use controls fail. However, for Alternative 1, changes in land use could result in the release of contaminants and cause potential future impacts on human health and the environment in the long term. Alternative 2 relies on limited site improvements and land use controls (limit land use and access to the property) and minimizes exposure to soils at the property, while allowing monitored natural attenuation to affect groundwater. In Alternative 2, all contamination is left in place, except for groundwater contamination, which will undergo passive remediation. If land use controls fail in Alternative 2, then the potential for exposure above both dose-based and risk-based standards is high. Alternative 3 relies on land use controls as a supplement to containment of the material. If land use controls fail in Alternative 3, then the potential for exposure above a dose-based standard is low. However, the potential for exposures above risk-based standards is high. Alternative 4 removes only the soils necessary to satisfy an industrial land use scenario. If land use controls fail in Alternative 4, then the potential for increase in dose-exposure is high. However, it would still be below the 100 mrem/yr limit for a residential scenario. Loss of land use controls in Alternative 4 also would result in the potential for exposure above risk-based standards. In Alternatives 5 and 6, the soil contamination is removed such that the site would be available for unrestricted use. No land use controls are proposed for control or restriction of the previously impacted soils, so there will be no impact if land use controls fail. If monitored natural attenuation is selected as the remedial measure for groundwater, for Alternatives 2, 3, 4, 5, and 6, then there is a slight potential for exposure to contaminated groundwater on site and to beryllium off site if land use controls fail during the remedial measure. Alternatives 7, 8, and 9 rely on the use of land use controls to control groundwater use for periods ranging from 40 to possibly as much as 1,000 years, but a period from 40 up to 150 years is the expected duration of land use controls. Should these controls fail, only wells deriving their water solely from the overburden would present a risk. Wells completed in the bedrock at depths (50 to 80 ft into the bedrock), typical for most domestic wells in the area, should continue to meet groundwater cleanup goals.

6.3.3 Short-term Uses and Long-term Productivity

Implementation of any set of alternatives would require the use of the Luckey site to support cleanup activities and the use of depletable resources, such as construction materials, fuel, and petroleum-based products. Alternatives that include excavation and disposal would require the long-term commitment of land for waste disposal either on site or at an off-site facility or facilities.

The short-term use of the site for remedial activities could adversely affect tenant operations. Planning will be done before implementation of any alternative to reduce risks to the current tenants and impact to operations. Long-term effect on the current tenants also will be taken into account when analyzing each alternative. Alternatives 1, 2, 3, and 4 could make transfer of the property from one owner to another more difficult while Alternatives 5 and 6 could facilitate such a transfer. Alternatives 7, 8, or 9 may increase the difficulty of transferring property since monitoring and treatment would need to be maintained.

The impact of the remediation on the local economy could be fairly significant. An outside contractor would be performing the work. Therefore, mostly secondary jobs would be impacted. Few local residents would be hired directly by the remediation contractors. However, the remediation workers would be spending money in the local economy for the duration of the remediation.

6.3.4 Final Status Surveys

USACE intends to use the MARSSIM (DoD 2000) to assure exposure to all radiological contaminants combined will not exceed dose-based limits. MARSSIM provides a consistent and scientifically rigorous approach for demonstrating compliance with dose-based limits, such as the 25 mrem/yr limit used at the Luckey site. The approach includes the development of surveying and sampling criteria for the final site investigation prior to release (called the “final status survey”). It considers COC concentrations averaged over entire exposure units or limited to small areas of elevated activity. A final status survey plan based on the MARSSIM methodology will be developed and implemented to assure that current or potential future doses are acceptable (as defined by the restrictions of remedial alternative).

MARSSIM is specifically designed for use with radionuclides and will not be applied to chemical contaminants. The specific list of radiological contaminants to be considered in the MARSSIM plan includes radium-226, thorium-230, uranium-234, and uranium-238. The corresponding dose-based cleanup levels are defined by MARSSIM as the derived concentration guideline level (DCGL). A DCGL applied over entire exposure units also is known as the $DCGL_w$, where the “w” subscript indicates the DCGL is averaged over a wide area and is used in statistical testing per MARSSIM. Small areas of elevated activity are evaluated through an elevated measurement comparison (EMC) and the associated DCGL is called the $DCGL_{EMC}$. In general, the EMC considers the following:

1. The relationship between dose and the physical size of an area of elevated activity – area factors are used to account for this relationship (area and dose are proportional for a fixed concentration, but the specific relationship must be defined) and
2. The ability to scan for radiological contaminants – surveying and sampling requirements may become more stringent if radiological contaminants can not be readily scanned.

In conclusion, the use of MARSSIM will assure that for each applicable alternative (i.e., Alternative 1 by definition will not include MARSSIM evaluations), radiological doses will be acceptable whether averaging across entire exposure units or considering small areas of elevated activity. In other words, soil concentrations of radium-226, thorium-230, uranium-234, and uranium-238 will be shown through a MARSSIM evaluation to be below the $DCGL_w$ and $DCGL_{EMC}$, corresponding to each applicable remedial alternative.

6.3.5 Considerations Common to Groundwater Alternatives

In addition to the items noted above, there are a number of considerations common to each of the groundwater alternatives. These considerations include the following:

- The preferred groundwater alternative will be implemented in conjunction with one of the soils alternatives (Alternatives 3, 4, 5, or 6). Alternatives 4, 5, and 6 remove the potential for further groundwater impacts. Alternative 3 reduces the potential of groundwater impact through infiltration, but may not address the potential interaction between groundwater and impacted materials in or near the trench bottoms.
- The clay-rich tills have the potential to retain beryllium, lead, and uranium through sorption for long periods of time. If this sorption process is reversible, contamination in groundwater

within the clay-rich tills could remain above ARARs for long periods of time (hundreds of years). These materials also may act as a source of contamination to sand and gravel or underlying carbonate bedrock aquifer and result in increased time frames for attainment of ARARs.

- Groundwater sampling results indicate decreasing trends in uranium and, to a lesser extent, lead concentrations, suggesting MNA may be an effective alternative.
- Recently observed variations in contaminant concentrations (from June 2001 and November 2001) may be indicative of seasonal fluctuations in beryllium, lead, and uranium concentrations or the result of direct contact between contaminant sources (base of trenches and Lagoon B).

6.4 COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES

In this section, the alternatives undergo a comparative analysis for the purpose of identifying relative advantages and disadvantages of each on the basis of the detailed analysis above. The comparative analysis provides a means by which remedial alternatives can be directly compared to one another with respect to common criteria. Overall protection and compliance with ARARs are threshold criteria that must be met by any alternative for it to be eligible for selection. The other criteria, consisting of short- and long-term effectiveness; reduction of contaminant toxicity, mobility, or volume through treatment; ease of implementation; and cost are the primary balancing criteria used to select a preferred remedy among alternatives satisfying the threshold criteria. A summary table illustrating the comparative analysis is provided as Table 6.3. Community and state acceptance criteria are preliminarily assessed in Table 6.3 and will be fully addressed after the public comment period.

Additional information pertaining to the advantages and disadvantages of each groundwater alternative are included in Table 6.4. Table 6.5 provides a summary of the predicted or expected timelines specific to the groundwater alternatives. Time frames are estimated during non-pumping and pumping conditions (i.e. while the East Production is simulated to be “off” as well as “on.”) Generally, the model indicates operation of the East Production Well shortens the time frame required to achieve cleanup goals in groundwater. It is important to note, the predicted time frames utilizing the groundwater model summarized in Table 6.5 assist in the comparison of alternatives. As with any modeling effort, uncertainty associated with input parameters, historical site operations, and contaminant distributions exist. Therefore, the estimated time frames presented in Table 6.5 for the selected remedies are likely to occur within a period of time similar to the time frame predicted by the groundwater model but not necessarily at the “exact” year.

6.4.1 Comparison Using NCP Criteria

6.4.1.1 Overall Protection of Human Health and the Environment

Each of the alternatives, except Alternative 1, is protective of human health and the environment. The degree of protection and the permanence of this protectiveness is a function of whether and to what extent the alternative utilizes engineering containment, removal, or land use control strategies. Alternative 1 is not considered protective for the long term because the BRA predicted that risks above the CERCLA acceptable range of 10^{-4} to 10^{-6} are possible if existing controls are not maintained and additional actions are not taken at the site. The excavation and off-site disposal alternatives (Alternatives 4, 5, and 6), when coupled with a groundwater alternative, rank highest in overall protection of human health and the environment because materials above media-specific cleanup goals (for industrial land use or unrestricted land use) are excavated and shipped off-site for disposal. For Alternatives 2 and 3, human health and the environment are protected as long as land use controls can be implemented and maintained. Otherwise, the potential future risk would be the same as for Alternative 1.

For Alternatives 3 through 6, a mitigation action plan would be developed during remedial design to specify measures that would be taken during implementation of the remedial action to minimize risk to human health and the environment (e.g., environmental controls and contingency response actions).

Alternatives 7, 8, and 9, when coupled with one of the soil remedial alternatives, are protective of human health and the environment. If coupled with Alternative 3, the potential for groundwater interactions with the base of the disposal trenches could result in periodic contaminant releases to the groundwater. Alternative 7 is expected to achieve ARARs within 40 to 150 years, Alternative 8 within 80 years, and Alternative 9 within 40 years after implementation. The major differences are the time frame in which land use controls are no longer necessary.

6.4.1.2 Compliance with ARARs

A summary of the proposed ARARs is presented under the ARARs discussion for Alternative 1 (Section 6.2.1.2). Alternatives 4, 5, and 6 satisfy all ARAR-based cleanup goals in soils. Alternatives 3 and 4 would achieve the 100 mrem/yr limit for unrestricted land use, even if land use controls fail. Alternative 2 would not satisfy these ARAR-based cleanup goals in soils without the implementation of land use controls. Alternatives 7, 8, and 9 satisfy all ARAR-based groundwater clean up goals when implemented in conjunction with one of the soil remedial alternatives. However, the time frame to achieve compliance may be as long as 40 to 150 years for Alternative 7. Alternative 1 does not achieve media-specific cleanup goals established by the ARARs.

6.4.1.3 Long-Term Effectiveness and Permanence

Human health risks remaining after remediation give an indication of the long-term effectiveness of an alternative. Human health risks due to exposure to contaminated materials will be reduced from the existing levels of risk by varying degrees, depending on the extent of remediation provided by the alternatives.

Alternatives 5 and 6, when coupled with one of the groundwater alternatives, provide the greatest long-term effectiveness because they would remove, for permanent off-site disposal, all soils above unrestricted land use cleanup goals. Alternatives 2, 3, and 4, which rely on land use controls to maintain protectiveness, are not as protective in the long term. Alternative 3, however, does permanently reduce the area associated with contamination and thereby reduces the overall risk and Alternative 4 does remove soils above the industrial land use cleanup goals. Alternative 1 would not be effective in the long term, since the contaminated materials would remain and would not be controlled. All of the groundwater alternatives provide long-term effectiveness when coupled with one of the soil remedial alternatives.

Pursuant to CERCLA, site remedy reviews would be conducted every five years for alternatives where contaminants (i.e., soil and groundwater) would remain on site above media-specific cleanup goals (except for the no action alternative). Because concentrations of some contaminants remain on site above the media-specific cleanup goals under Alternatives 1, 2, 3, and 4, a review would be conducted at least once every five years. These reviews would not be necessary for Alternatives 5 and 6 since verification sampling would be performed at the time of remedy implementation showing that impacted soils above unrestricted land use cleanup goals were removed. Groundwater remediation will necessitate five-year reviews in Alternatives 7, 8, and 9 until the contaminants have attenuated to a concentration allowing unlimited use and unrestricted exposure.

6.4.1.4 Reduction in Contaminant Volume, Toxicity, and Mobility through Treatment

Alternative 6 is the only alternative that incorporates treatment of soils, and would effect a reduction in contaminant volume. This reduction is estimated for costing purposes to be 50 percent of the throughput (Appendix 6B). Alternatives 8 and 9 reduce the volume of the contaminated groundwater through treatment. The contaminants would be trapped in a solid matrix or solidified so that their mobility also is reduced.

6.4.1.5 Short-Term Effectiveness

The biggest difference in short-term effectiveness is due to the potential for accidents from the consolidation, excavation, and transportation of soil. Increased potential for exposure to contaminated media also increases under soil and groundwater treatment scenarios. Under Alternatives 3, 4, 5, and 6, short-term risks due to accidents for workers and the public are increased because of the consolidation, excavation, and off-site transportation involved. Under Alternative 6, there are additional short-term risks due to the treatment of soil. Short-term risks also are increased for Alternatives 3, 4, 5, and 6, if treatment of groundwater (Alternative 8 or 9) is implemented. Alternative 2 has the least potential for short-term negative impacts to workers, the community and the environment during implementation because it only requires limited site improvements and maintenance of the current status quo. Alternatives 7, 8, and 9 involve increasing risk to workers due to activities necessary to the alternative. These increased risks are due to well drilling installation of system piping and a filtration system, installation of power systems (including a 480 volt ground level system for Alternative 9), and handling of filter media and electrolytes. Among the groundwater alternatives, the short term risks are greatest for Alternative 9 and least for Alternative 7.

Short-term negative impacts to the environment are likely to occur with soil consolidation or excavation considered as part of Alternatives 3, 4, 5, and 6. These impacts also are likely with the groundwater alternatives due to the drilling of monitoring and extraction wells and the construction of treatment facilities. Excavation and consolidation potentially destroy animals and plants at the excavated locations and existing features of the environment that may provide habitat or food to plants and animals. The degree of short-term damage to the environment increases with the amount of surface area subjected to disturbance.

6.4.1.6 Implementability

This criterion addresses the ability to technically accomplish the remedy; the ability to obtain approvals and coordinate with other authorities (i.e., administrative feasibility); and the availability of materials and services required for the cleanup. Materials and services for removal of contamination and environmental monitoring activities for the various alternatives are readily available. The degree of difficulty in implementing alternatives increases with the amount and type (i.e., accessible soils) of impacted soils to be excavated, the level of the design/transportation required to dispose of soils in accordance with regulations, and the time/coordination involved in completing the alternative.

All action alternatives are considered implementable on a technical and an availability-of-services basis. Alternative 3 involves consolidation and capping and uses readily available technology and equipment. Alternatives 4, 5, and 6 involve excavation and off-site disposal, and also use readily available technology and equipment. Alternative 6 also is considered implementable, although it involves greater uncertainties with respect to treatment performance. The proposed soil treatment process is available from commercial sources, and has been effectively demonstrated in other applications. The same is true for all groundwater treatment technologies considered under Alternatives 7, 8, and 9. Alternative 9 requires treatment units that are commercially available, but whose effectiveness has not

been demonstrated. Alternative 9 is therefore considered moderately technically feasible. All the groundwater alternatives rely, to some extent, on land use controls, as do Alternatives 2, 3, and 4. The implementability of these controls is proportional to the duration. Long durations of control will be more difficult to implement.

Alternatives 5 and 6 are most easily implemented on an administrative basis. These alternatives forgo the need to meet substantive disposal permit requirements and land use controls for soil remediated areas. Alternative 3 would be difficult to implement on an administrative basis because of the need for meeting substantive permit requirements relating to solid, hazardous, and/or radioactive wastes. Alternatives 2 and 4 also would be difficult to implement on an administrative basis, but the difficulty here would arise from implementing, maintaining, and enforcing the necessary land use controls for the required duration. Alternatives 7 and 8 would be difficult to implement administratively due to the long time frames involved.

6.4.1.7 Cost

The estimated present value cost (in FY 2002 dollars with a seven percent discount factor) to complete each of the alternatives is as follows:

- Alternative 1: \$ 0.0 million
- Alternative 2: \$ 1.1 million
- Alternative 3: \$17.6 million
- Alternative 4: \$29.3 million
- Alternative 5: \$36.5 million
- Alternative 6: \$42.8 million
- Alternative 7: \$ 0.83 million
- Alternative 8: \$ 3.7 million
- Alternative 9: \$ 9.4 million

Detailed descriptions of the costs for each alternative, itemization of individual components, assumptions, and sensitivity analyses are provided in Appendix 6B.

Table 6.1. Estimated Completion Time Frames for Alternatives

Alternative	Remedial Design (years)	Remedial Action (RA) (years)	Post RA Documentation (years)	O & M Period (years)
Alternative 1: No Action (Soils and Groundwater)	0	0	0	0
Alternative 2: Limited Action (Soils and Groundwater)	0.5	0	0	1,000
Alternative 3: Consolidation and Capping (Soils)	2	2	1	1,000
Alternative 4: Excavation of Soils and Off-site Disposal (Soils) ~ Industrial Land Use	1	1.7	1	1,000
Alternative 5: Excavation of Soils and Off-site Disposal (Soils) ~ Unrestricted Land Use	1	2.9	1	0
Alternative 6: Excavation of Soils, Treatment, and Off-site Disposal (Soils) ~ Unrestricted Land Use	2	3	1	0
Alternative 7: Monitored Natural Attenuation (Groundwater) ~ Unrestricted Land Use	0.5	0	1	40 to 150
Alternative 8: Active Groundwater Treatment (Groundwater) ~ Unrestricted Land Use	1	0.5	1	80
Alternative 9: Electrokinetics (Groundwater) ~ Unrestricted Land Use	1	1	1	40

NOTE: See Appendix 6B for explanation of estimated completion time frames.

Table 6.2 Summary of Detailed Analysis of Remedial Alternatives

NCP Evaluation Criteria	Alternative 1 No Action (Section 6.2.1)	Alternative 2 Limited Action (Section 6.2.2)	Alternative 3 Consolidation and Capping (Section 6.2.3)	Alternative 4 Excavation and Off-site Disposal (Industrial Land Use) (Section 6.2.4)	Alternative 5 Excavation and Off-site Disposal (Unrestricted Land Use) (Section 6.2.5)	Alternative 6 Excavation, Treatment, and Off-site Disposal (Unrestricted Land Use) (Section 6.2.6)	Alternative 7 Monitored Natural Attenuation (Unrestricted Land Use) (Section 6.2.7)	Alternative 8 Active Groundwater Treatment (Unrestricted Land Use) (Section 6.2.8)	Alternative 9 Electrokinetics (Unrestricted Land Use) (Section 6.2.9)
(1) OVERALL PROTECTIVENESS									
Human Health Protection	Not protective due to risk from exposure.	Not protective due to use of land use controls.	Protective due to reduction of contaminated area and mitigation of exposure pathways due to capping, and land use controls.	Protective due to removal of impacted soils from site and land use controls.	Protective due to removal of impacted soils from site.	See Alternative 5.	Protective due to natural attenuation and mitigation of exposure pathways due to land use controls.	Protective due to treatment of groundwater and land use controls.	See Alternative 7.
Environmental Protection	Continued potential for adverse impacts from existing conditions; however, habitat and receptors are limited.	See Alternative 1.	Action designed to address human health risks; however, this also will reduce risks to ecological receptors due to removal of impacted soils from site.	Action designed to address human health risks; however, this also will reduce risks to ecological receptors due to removal of impacted soils from site.	Action designed to address human health risks; however, this also will reduce risks to ecological receptors due to removal of impacted soils from site.	See Alternative 5.	Groundwater is not an ecological concern until it becomes surface water.	See Alternative 6.	See Alternative 6.
(2) COMPLIANCE WITH ARARs									
ARARs	Not compliant.	Would not comply for unrestricted release of property, property would not be released for unrestricted use.	Comply for industrial land use. Would not comply for unrestricted release of properties, portion of property would not be released for unrestricted use.	Comply for industrial land use. Would not comply for unrestricted release of property, property would not be released for unrestricted use.	Compliant.	Compliant.	Compliant in approximately 40 to 150 years.	Compliant in approximately 80 years.	Compliant in approximately 40 years.
(3) LONG-TERM EFFECTIVENESS AND PERMANENCE									
Magnitude of Residual Risk	Residual risk exceeds EPA risk range due to waste remaining in current configurations, thereby allowing for potential future exposure.	Residual risk is acceptable as long as land use controls are implemented and remain in place.	See Alternative 2.	See Alternative 2.	Meets risk range without restrictions on future land use. Less residual risk than Alts 1, 2, & 3.	See Alternative 5.	Meets risk range without restrictions. Would require a longer time frame to achieve than Alts 7 and 8.	Meets risk range without restrictions.	See Alternative 8.

Table 6.2 Summary of Detailed Analysis of Remedial Alternatives

NCP Evaluation Criteria	Alternative 1 No Action (Section 6.2.1)	Alternative 2 Limited Action (Section 6.2.2)	Alternative 3 Consolidation and Capping (Section 6.2.3)	Alternative 4 Excavation and Off-site Disposal (Industrial Land Use) (Section 6.2.4)	Alternative 5 Excavation and Off-site Disposal (Unrestricted Land Use) (Section 6.2.5)	Alternative 6 Excavation, Treatment, and Off-site Disposal (Unrestricted Land Use) (Section 6.2.6)	Alternative 7 Monitored Natural Attenuation (Unrestricted Land Use) (Section 6.2.7)	Alternative 8 Active Groundwater Treatment (Unrestricted Land Use) (Section 6.2.8)	Alternative 9 Electrokinetics (Unrestricted Land Use) (Section 6.2.9)
Adequacy and Reliability of Controls	No land use controls.	Land use controls considered adequate.	See Alternative 2.	See Alternative 2.	No land use controls required.	See Alternative 5.	Land use controls required and considered adequate while MNA works.	Land use controls required and considered adequate for duration of treatment.	Land use controls required and considered adequate for duration of treatment.
Long-Term Management	No long-term management.	Required since soils would remain on site above criteria for unrestricted use.	See Alternative 2.	See Alternative 2.	Not required.	See Alternative 5.	Required for up to 150 years or duration of treatment.	Required for 80 years.	Required for 40 years.
(4) REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT									
Reduction through Treatment.	None (no treatment).	See Alternative 1.	None.	None.	None.	Volume reduction.	None.	Volume and mobility reduction.	See Alternative 8.
(5) SHORT-TERM EFFECTIVENESS									
Community	Risk to community not increased, but potential contaminant migration and increased exposure over time.	See Alternative 1, although least risk to community.	Slight potential for an increase in risk from construction activities. Site risks would be controlled by mitigation measures.	See Alternative 3. Transportation risks introduced with off-site disposal.	See Alternative 3. Transportation risks introduced with off-site disposal.	See Alternative 5. Potential increase in risk due to additional materials handling during treatment. Site safety measures would be implemented to control risks.	Slight potential for an increase in risk during well installation activities. Site risks would be controlled by mitigation measures.	Slight potential for an increase in risk during well installation activities. Site risks would be controlled by mitigation measures.	Potential for an increase in risk from construction and implementation activities. Site risks would be controlled by mitigation measures.
Workers	No significant increase of risks or hazards to workers.	See Alternative 1.	Radiological risks and non-radiological hazards reduced by mitigation measures. Site safety measures would be implemented.	See Alternative 3.	See Alternative 3.	See Alternative 3. Potential for additional risks due to materials handling during treatment. Site safety measures would be implemented.	Slight potential of radiological and non-radiological hazards reduced by mitigation measures.	See Alternative 6. Potential for additional risks due to materials handling during treatment. Site safety measures would be implemented.	See Alternative 6. Potential for additional risks due to materials handling during treatment and electrical system needed for electrodes. Site safety measures would be implemented.
Ecological Resources	Continued potential for impacts from existing conditions.	Continued potential for impacts from existing conditions.	Potential short-term environmental impacts minimized by Engineering controls.	See Alternative 3.	See Alternative 3.	See Alternative 3.	Slight impact.	See Alternative 7.	Potential short-term environmental impacts minimized by Engineering controls.

Table 6.2 Summary of Detailed Analysis of Remedial Alternatives

NCP Evaluation Criteria	Alternative 1 No Action (Section 6.2.1)	Alternative 2 Limited Action (Section 6.2.2)	Alternative 3 Consolidation and Capping (Section 6.2.3)	Alternative 4 Excavation and Off-site Disposal (Industrial Land Use) (Section 6.2.4)	Alternative 5 Excavation and Off-site Disposal (Unrestricted Land Use) (Section 6.2.5)	Alternative 6 Excavation, Treatment, and Off-site Disposal (Unrestricted Land Use) (Section 6.2.6)	Alternative 7 Monitored Natural Attenuation (Unrestricted Land Use) (Section 6.2.7)	Alternative 8 Active Groundwater Treatment (Unrestricted Land Use) (Section 6.2.8)	Alternative 9 Electrokinetics (Unrestricted Land Use) (Section 6.2.9)
Engineering Controls	None.	See Alternative 1.	Potential releases controlled with management and engineering practices.	See Alternative 3.	See Alternative 3.	See Alternative 3.	See Alternative 3.	See Alternative 3.	See Alternative 3.
Time to Complete ¹	0 years	0 years	2 years	1.7 years	2.9 years	3 years	0 years	0.5 years	1 year
O & M Period	0 years	1,000 years	1,000 years	1,000 years	0 years	0 years	40 to 150 years	80 years	40 years
(6) IMPLEMENTABILITY									
Technical Feasibility	Not applicable.	Relatively easy.	Relatively easy. Readily available technology.	Relatively easy. Readily available technology.	Relatively easy. Readily available technology.	Moderate. Treatment units available commercially, but effectiveness must be demonstrated.	Relatively easy. Readily available technology.	Relatively easy. Readily available technology.	Moderate. Treatment units available commercially, but effectiveness must be demonstrated.
Administrative Feasibility	Not applicable.	May be difficult due to meeting substantive requirements the state has for licensing.	See Alternative 2.	See Alternative 2.	Relatively easy.	Would require meeting substantive requirements for placing “clean” soils back on site.	See Alternative 4.	See Alternative 4.	See Alternative 4.
(7) COST									
Estimated cost ²	\$0.0 million	\$1.1 million	\$17.6 million	\$29.3 million	\$36.5 million	\$42.8 million	\$0.83 million	\$3.7 million	\$9.4 million.
Cost with Alt 7	Not applicable.	Not applicable.	\$18.4 million	\$30.1 million	\$37.3 million	\$43.6 million	Not applicable.	Not applicable.	Not applicable.
Cost with Alt 8	Not applicable.	Not applicable.	\$21.3 million	\$33.0 million	\$40.2 million	\$46.5 million	Not applicable.	Not applicable.	Not applicable.
Cost with Alt 9	Not applicable.	Not applicable.	\$27.0 million	\$38.7 million	\$45.9 million	\$52.2 million	Not applicable.	Not applicable.	Not applicable.

¹ Time to complete remedial action after completion of remedial design, assuming timely project funding. Does not include O & M period.

² Estimated costs calculated as net present value in FY 02 dollars using a seven percent discount factor.

Table 6.3 Summary of Comparative Analysis of Remedial Alternatives

NCP Evaluation Criteria	Alternative 1 No Action (Section 6.2.1)	Alternative 2 Limited Action (Section 6.2.2)	Alternative 3 Consolidation and Capping (Section 6.2.3)	Alternative 4 Excavation and Off-site Disposal (Industrial Land Use) (Section 6.2.4)	Alternative 5 Excavation and Off-site Disposal (Unrestricted Land Use) (Section 6.2.5)	Alternative 6 Excavation, Treatment, and Off-site Disposal (Unrestricted Land Use) (Section 6.2.6)	Alternative 7 Monitored Natural Attenuation (Unrestricted Land Use) (Section 6.2.7)	Alternative 8 Active Groundwater Treatment (Unrestricted Land Use) (Section 6.2.8)	Alternative 9 Electrokinetics (Unrestricted Land Use) (Section 6.2.9)
(1) Overall Protection of Human Health and the Environment (6.4.1.1)	Low	Low	Medium	Medium	High	High	Low / Medium	High	High
(2) Compliance with ARARs (6.4.1.2)	Low	Low	Medium / High	Medium / High	High	High	Low / Medium	High	High
(3) Long-Term Effectiveness and Permanence	Low	Low	Medium	Medium	High	High	Medium	High	High
(4) Reduction of Toxicity, Mobility, or Volume through Treatment (6.4.1.4)	Low	Low	Low	Low	Low	Medium	Medium	High	High
(5) Short-Term Effectiveness (includes potential for environmental impacts) (6.4.1.5) Time to complete 1 O&M Period.	Low 0 years 0 years	Low 0 years 1,000 years	Medium 2 years 1,000 years	Medium 1.7 years 1,000 years	Medium 2.9 years 0 years	Medium 3 years 0 years	High 0 years 40 to 150 years	Medium 0.5 years 80 years	Low 1 year 40 years
(6) Implementability (6.4.1.6)	High	Low	Low / Medium	Medium	High	Medium	High	Medium	Medium
(7) Cost 2 (6.4.1.7)	\$0	\$1.1 million	\$17.6 million	\$29.3 million	\$36.5 million	\$42.8 million	\$0.83 million	\$3.7 million	\$9.4 million
<i>Preliminary Evaluation of Regulatory and Public Input</i>									
(8) State / Agency Acceptance	Low	Low	Low / Medium	Low / Medium	High	High	Low	Medium	High
(9) Community Acceptance	Low	Low	Low	Low / Medium	High	Medium	Low	Medium	High

¹ Time to complete remedial action after remedial design, is dependent upon timely project funding. Does not include O & M.

² Estimated costs calculated as net present value in FY 02 dollars using a seven percent discount factor.

Table 6.4. Advantages/Disadvantages of Groundwater Alternatives for Comparative Analysis

Alternative	Advantages	Disadvantages
Alternative 7: Monitored Natural Attenuation	<ul style="list-style-type: none"> Observed data for uranium and to lesser extent lead suggest decreasing trends suggesting already effective Predicted times: lead < 5 yrs; uranium < 30 yrs; beryllium < 40 for bedrock, <150 for sand & gravel Applies to all areas of the site Small or negligible volume of Investigative Derived Waste (IDW) Lower overall costs 	<ul style="list-style-type: none"> Contamination in clay-rich tills could increase time frame for effectiveness Requires extensive performance monitoring program Potential for contaminant migration Relatively long time period for beryllium in sand and gravel (long term monitoring) Public perception as “no action” alternative for groundwater Land use controls required until attainment of beneficial reuse status (until all ARARs are met)
Alternative 8: Active Groundwater Treatment – Ex situ	<ul style="list-style-type: none"> Effective for remediation of groundwater in sand and gravel and carbonate bedrock aquifer Time to achieve ARARs is predicted to be maximum of 50 to 80 years Predicted times: lead < 1 year; uranium < 10 years; beryllium <25 years for bedrock < 80 years for sand & gravel Controls/eliminates potential for contaminant migration to receptors Reduces contaminant mass/concentration in the groundwater 	<ul style="list-style-type: none"> Ineffective for contamination in clay-rich tills Flow field variability from operation or shut down of the East Production Well impacts extraction well placement Relatively small cone of influence due to shallow contamination (thin zone for pump and treat) may require closer well spacing System installation and maintenance costs are relatively high Construction and operation of treatment facility that may require maintenance beyond typical design life Time period for completion up to 80 years Generates large volumes of water to be treated and disposed Possible recontamination after system shutdown Land use controls required until attainment of beneficial reuse status (until all ARARs are met)
Alternative 9: Electrokinetics	<ul style="list-style-type: none"> Addresses contaminated groundwater within the clay-rich till and sand and gravels Controls or eliminates potential future migration of contaminants Predicted times: completion ~ 15 years for clay-rich tills; <40 years for bedrock 	<ul style="list-style-type: none"> Does not address contaminated groundwater in carbonate bedrock Significant system installation and operation costs (including a pilot study to determine effectiveness) Construction and operation of treatment system that may require maintenance beyond typical design life IDW generated during installation (approximately 15 drums each of liquid waste for beryllium and uranium -30 total drums). Land use controls required until attainment of beneficial reuse status (until all ARARs are met)

Table 6.5. Time Frames for Alternative 7 - MNA and Alternative 8 - Active Pump and Treat at Luckey under Non-Pumping and Pumping Conditions

Constituent	Location	Alternative 7 Monitored Natural Attenuation			Alternative 8 Active Groundwater Treatment		
		Clay-Rich Till	Sand & Gravel	Bedrock	Clay-Rich Till	Sand & Gravel	Bedrock
NON-PUMPING CONDITIONS							
Beryllium	MW-01(I)	--	60	12	--	14	2
	MW-26(S)	--	150	40	--	50-80	25
	PW(W) ¹	--	0	3.5	--	0	1
Lead	MW-21(I) ²	--	0	3.5	--	0	0.5
	MW-24(S) ³	400-600	--	3.5	200-400	--	1
Uranium	MW-24(S)	>1,000	--	30	200-500	--	10
PUMPING CONDITIONS							
Beryllium	MW-01(I)	--	1.5	4.5	--	3.5	3
	MW-26(S)	--	175	40	--	90	26
	PW(W) ¹	--	0	1	--	0	1
Lead	MW-21(I) ²	--	0	1.2	--	0	0.5
	MW-24(S) ^{3,4}	400-600	--	NA	200-400	--	NA
Uranium	MW-24(S) ⁴	>1000	--	NA	200-500	--	NA

¹—Simulations for beryllium at PW(W) were initiated with beryllium in the bedrock only, and concentrations never exceed ARAR-based cleanup goals in the sand and gravel.

²—Simulations for lead at MW-21(I) were initiated with lead in the upper weathered bedrock only, and concentration never exceed ARAR-based cleanup goals in the overlying sand and gravel.

³—Sand and gravel does not occur at MW-24(S) and therefore, no time frames are reported for both uranium and lead at this location.

⁴—Simulations for lead and uranium under pumping conditions were completed with the source term (starting concentrations) released in the overburden. No simulations were run with the source term released only in the upper bedrock, and therefore, time frames are not reported for the bedrock for lead and uranium at MW-24(S).

Note: The time frames in Table 6.5 are based upon predictive modeling results. Modeling was not performed for electrokinetics. Estimated total time for the completion of groundwater remediation using electrokinetics is 15 years for the clay-rich tills and the sands and gravels. Remediation of groundwater in the carbonate bedrock is assumed to be similar in duration to MNA for achievement of ARARs since electrokinetics may not be effective (< 40 years). Long time frames for achievement of ARARs are possible (as predicted from modeling) for groundwater in the clay-rich till. In particular, the area around MW-24(S) results in significant time frames for both MNA and pump and treat evaluations if constituents occur within the clay-rich till above the weathered bedrock. MW-24(S) is completed across the interface between the clay-rich till and the upper weathered bedrock. Based upon the lithologic log for MW-24(S), clay-rich till occur immediately above the bedrock (there is no significant sand and gravel identified in the log for MW-24(S)). Therefore, no time frames are reported in Table 6.5 for sand and gravel at MW-24(S) for either lead or uranium.

7.0 AGENCY COORDINATION AND PUBLIC INVOLVEMENT

This section reviews actions that have been conducted and that are planned in the future to ensure regulatory agencies and the public have been provided with appropriate opportunities to stay informed of progress on the Luckey site remediation and to provide meaningful input on the planning effort as well as the final selection of a remedy.

As described in Section 6, two of the nine NCP evaluation criteria are known as “modifying criteria.” These are State Acceptance and Community Acceptance. These criteria provide a framework for obtaining the necessary agency coordination and public involvement in the remedy selection process.

7.1 STATE ACCEPTANCE

State Acceptance considers comments received from agencies of the State of Ohio. The primary state agencies supporting this investigation are the Ohio EPA and the Ohio DOH.

Input has been encouraged during the ongoing investigation process to ensure the remedy ultimately selected for the Luckey site meets the needs of the State of Ohio. Final comments will be received from state agencies after this FS and the Proposed Plan (PP) are issued. These comments will be considered in the final selection of a remedy. Responses to comments will be addressed in the responsiveness summary of the subsequent Record of Decision (ROD).

7.2 COMMUNITY ACCEPTANCE

Community acceptance considers comments made by the community on the alternatives being considered. CERCLA 42 U.S.C. 9617(a) emphasizes early, constant, and responsive community relations. The USACE has prepared a Community Relations Plan (USACE 1999a) for this project to ensure the public has convenient access to information regarding project progress. The community relations program interacts with the public through news releases, public meetings, public workshops, meetings with local officials and interest groups, and also receives and responds to public comments through correspondence and the USACE FUSRAP Public Information Center.

CERCLA 42 U.S.C. 9617(a) requires that an Administrative Record be established “at or near the facility at issue.” Relevant documents regarding the Luckey site have been made available to the public for review and comment. The Administrative Record for the Luckey project is available at the following locations:

Luckey Public Library

228 Main Street, Box 190

Luckey, OH 43443

Contact: Carol Gambrell at (419) 833-6040.

USACE FUSRAP Public Information Center

1776 Niagara Street

Buffalo, NY 14207

(800) 833-6390 and press “5” at the recorded message.

The Luckey Partnering Team was established in 1999 to facilitate the open exchange of information with the community. Members of the Partnering Team represent regulatory agencies, local government entities, and property owners. The Partnering Team has held regular meetings to receive

input on the remediation process and to provide comments on draft technical documents. It is anticipated that the Partnering Team will continue its mission through the acceptance of the ROD.

In addition to formulating the Partnering Team, USACE contacted the Technical Outreach Services for Communities (TOSC). The mission of the TOSC program is to work directly with communities on hazardous-substance pollution problems. By providing independent technical information and assistance, TOSC gives communities the means to understand technical and engineering issues and to participate in environmental decisions, including cleanup decisions. Thirty universities nationwide provide the foundation of support to TOSC, through the five Hazardous Substance Research Centers (HSRCs) serving several EPA Regions, including Region 5. Funding for the HSRCs is provided by: EPA, the Department of Defense, the Department of Energy, other state and federal agencies, participating universities, and private sources.

The Great Lakes and Mid-Atlantic HSRC and the Great Lakes and Mid-Atlantic TOSC are led by the University of Michigan. USACE invited this chapter of TOSC to attend an informational public meeting in Luckey, Ohio on June 15, 1999. At this meeting, TOSC gave a presentation on its activities and forms of assistance. TOSC met with the community members before and after the meeting to discuss their concerns regarding the site. A subsequent public meeting was held March 23, 2000. At this meeting, a TOSC representative was invited to speak and reported to the public that the organization had spoken with members of the community and that, in general, the community seemed satisfied with the performance of USACE. As a result, the TOSC representative reported the organization would not stay involved unless an organized group of community members could make a commitment to TOSC to work with it and express areas where assistance was necessary. Due to lack of response, the TOSC decided to end its involvement in the project. However, TOSC can be reached at 1-800-490-3890 and on the World Wide Web at www.toscprogram.org for further discussion about possible involvement if the community believes the organization could be of assistance.

Similar to state agencies, final comments will be received from the community after the FS and PP are issued. These comments will be considered in the final selection of a remedy. Responses to these comments will be addressed in the responsiveness summary of the ROD.

8.0 CONCLUSION

The CERCLA process consists of a preliminary assessment, site inspection, remedial investigation, and feasibility study, followed by remedy selection in the proposed plan, record of decision, remedial design, and remedial action. To date, several of these steps have been completed. These efforts have compiled and evaluated essential information characterizing the nature and extent of contamination resulting from past operations at the Luckey site.

The primary purpose of this FS is to develop, screen, and evaluate remedial alternatives using the data collected during previous investigations. This FS examined the history of the Luckey site and previous investigations, developed media-specific cleanup goals and remedial actions objectives for the site, and screened a range of technologies potentially applicable for meeting these cleanup goals. The most promising technologies were assembled into the following remedial alternatives:

- Alternative 1: No Action (Soils and Groundwater)
- Alternative 2: Limited Action (Soils and Groundwater)
- Alternative 3: Consolidation and Capping (Soils)
- Alternative 4: Excavation of Soils and Off-site Disposal (Soils) ~ Industrial Land Use
- Alternative 5: Excavation of Soils and Off-site Disposal (Soils) ~ Unrestricted Land Use
- Alternative 6: Excavation of Soils, Treatment, and Off-site Disposal (Soils) ~ Unrestricted Land Use
- Alternative 7: Monitored Natural Attenuation (Groundwater) ~ Unrestricted Land Use
- Alternative 8: Active Groundwater Treatment – Ex Situ (Groundwater) ~ Unrestricted Land Use
- Alternative 9: Electrokinetics (Groundwater) ~ Unrestricted Land Use.

The alternatives were analyzed and compared to assist in the ultimate selection of a site remedy. Site characterization data and a number of analytical tools provided the foundation for evaluation of the alternatives. These tools included: evaluation of the nature and extent of contamination, analysis of contaminant fate and transport characteristics, and results of the baseline risk assessment. Other analytical tools employed in the detailed evaluation of alternatives included cost estimating and modeling. Groundwater flow conditions and contaminant transport at the site were evaluated through the development of a groundwater flow model (USACE 2001a). Modeling provided a predictive analysis, while considering historical information and site characterization data.

The detailed and comparative analysis showed that Alternatives 5 and 6 for soil and Alternatives 7, 8, and 9 for groundwater met media-specific cleanup goals and allowed the site to be released for unrestricted use. Alternative 4 provides overall protection and meets the ARAR dose limits even if land use controls fail. However the site could not be released for unrestricted use because beryllium and lead would remain above unrestricted land use cleanup goals. Alternative 3 provided overall protection, but would not allow portions of the site to be released for unrestricted use. Alternative 2 provided overall protection, but would not allow the site to be released for unrestricted use. Alternative 1 is not protective and therefore would not allow the site to be released for unrestricted use.

The estimated costs for addressing soils in Alternatives 5 and 6 are much greater than Alternatives 2 and 3, but Alternatives 5 and 6 do not leave contaminated material on site. Although Alternative 4 is less costly than Alternatives 5 and 6, its associated land-use controls add future uncertainty. The inclusion of treatment of soil in Alternative 6 does not provide a significant cost benefit over soil excavation and direct disposal alone (Alternative 5). The treatment of groundwater in Alternatives 8 and 9 is more costly in the short-term than Alternative 7 however the duration of time to

achieve free release is shorter. The timeframe to achieve groundwater cleanup goals is shortest under Alternative 9.

The next step in the CERCLA process is to prepare a PP to solicit public input on the remedial alternatives. The PP will present alternatives evaluated in the FS together with the preferred alternative for remediating the Luckey site. The draft PP will be submitted to the EPA, Ohio EPA, and members of the Partnering Team for review. Public comments received on the PP also will be evaluated.

The ROD will select the final remedy for the Luckey site. Comments on the PP received from state and federal agencies and the public will be considered in drafting the ROD. The ROD will describe the CERCLA selection process and provide a brief summary of the history, characteristics, risks, and alternatives for site remediation. The ROD also will include a responsiveness summary, addressing comments received on the PP.

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